THE JOURNAL OF ENGINEERING EDUCATION

Published by the Society for the Promotion of Engineering Education

Published under the supervision of the Publication Committee.
Dexter S. Kimball, R. L. Sackett, F. L. Bishop, Editor, University of Pittsburgh.
Published at Lancaster, Pa.

Entered as second-class matter at the Post Office at Lancaster, Pa., under the Act of March 3, 1870.

New Series
Vol. XIX, No. 2. OCTOBER, 1928 Subscription Price, $3.00 per year. Single Copies, 50 cents

TABLE OF CONTENTS.

Better Textbooks. Dexter S. Kimball, President of the Society.... 147
The Institutional Division and Engineering Education, F. L. Bishop, Secretary 149
Review of the Report of the Board of Investigation and Coordination as Related to the Engineering School at the University of North Carolina. G. M. Braune..... 151
Survey, an Orientation and Motivation Course. L. O. Stewart.... 158
Report on Future Organization and Activity. W. E. Wickenden.. 161
Discussion:
H. J. Hughes 181
A. A. Potter 185
Report of Committee on Policy on "Report on Future Organization and Activity." 187
Our Debt to the Electricians of the Nineteenth Century. Henry Crew 188
Report on Technical Nomenclature..... 220
Joint Session of S. P. E. E. and A. S. M. E..... 223
The Physics Division 224
College Notes:
University of Kansas 225
Pratt Institute 225
Request for Inventions of Octave Chanute 226
Book Reviews 227

HEADQUARTERS OF THE SOCIETY

UNIVERSITY OF PITTSBURGH, PITTSBURGH, PA.

OFFICERS OF THE SOCIETY, 1928–29

President

DEXTER S. KIMBALL, Cornell University, Ithaca, N. Y.

Vice-Presidents

C. C. WILLIAMS, University of Iowa, Iowa City, Iowa.
G. M. BRAUNE, University of North Carolina, Chapel Hill N. C.

Secretary

F. L. BISHOP, University of Pittsburgh, Pittsburgh, Pa.

Treasurer

W. O. WILEY, Jno. Wiley & Sons, New York City

Assistant Secretary

NELL MCKENRY, University of Pittsburgh, Pittsburgh, Pa.

BOARD OF INVESTIGATION AND COORDINATION

BISHOP, F. L., *Secretary,* University of Pittsburgh, Pa.
JACKSON, D. C., Massachusetts Institute of Technology, Cambridge, Mass.
KIMBALL, D. S., Cornell University, Ithaca, N. Y.
SACKETT, R. L., Pennsylvania State College, State College, Pa.
SCOTT, CHAS. F., *Chairman,* Yale University, New Haven, Conn.
TURNEAURE, F. E., University of Wisconsin, Madison, Wis.

WICKENDEN, W. E., Director of Investigations, 33 West 39th Street, New York City.
HAMMOND, H. P., Associate Director, 33 West 39th Street, New York City.
SPAHR, R. H., Member of Staff, 33 West 39th Street, New York City.

BETTER TEXTBOOKS.

BY DEXTER S. KIMBALL,

President of the Society.

In all the discussion of this investigation of better methods of teaching, little has been said about textbooks, though perhaps there is no single item that could more profitably engage our attention.

Lecturing as a means of imparting knowledge is admittedly an imperfect method, good lecturers are very rare and I fear becoming increasingly more so. Our greatest dependence is placed upon good textbooks and their use as a basis for recitation and laboratory instruction. It is admitted, of course, that a good lecturer is always an inspiring influence, but lecturing at best has limitations.

Good, clearly-written and well-arranged textbooks are almost as rare as good lecturers. It is amazing what some experienced teachers will put into textbooks. The writer is reminded of a certain book on physics, written by an experienced teacher, that contained the following definition—"A magnet is a piece of steel that has been treated in a manner to be described hereafter." This is equalled only by this definition in another textbook—"A washer is a circular piece of metal with a hole attached." Now it is not contended that these are typical of textbooks in general, but it is true that our textbooks, as a rule, do not have the clear and lucid explanations that they should have and as are to be found in the best of such books that are intended to be used independently of a teacher. Our texts on the basic sciences, mathematics, physics, and chemistry are equally faulty in this respect.

Again why should textbooks differ so widely in their method of approach to the subject. The number of textbooks, for instance, on mechanism, a basic subject that has made little fundamental progress since the day of Reuleaux is simply

astonishing. Many of our texts are too large for beginning courses. Many writers in their intense desire to exhaust the subject produce volumes so large that their very bulk discourages the student and furthermore, these large books are too expensive and add considerably to the cost of education, which already is very heavy.

The writer is aware that he lays himself open to attack having written some textbooks himself and he remembers that Solomon (a writer of note) remarked, "Oh, that my adversary had written a book." Apparently book reviewers existed in his day and their habits have not changed with the passing years.

But seriously the writer would like to see some earnest discussion of this most important phase of our work. Without doubt there is a great opportunity for improvement in the basic means of instruction.

THE INSTITUTIONAL DIVISION AND ENGINEERING EDUCATION.

F. L. BISHOP,
Secretary, S. P. E. E.

There have been many discussions and much written concerning the functions of the Institutional Division. It would seem to me that Dean C. E. Magnusson, during his term as Chairman of this Division in 1927–28, suggested a step which looks toward a more effective organization of this Division. His suggestion was that official representatives be appointed in each institution who would serve during the year as contact agents between the Society and the institutions and that these representatives should in general be the delegates to the next annual meeting. Thus, if the officers of the Society or any committee desired to send a communication from the Society to its institutional members, there is an established representative in each institution who can present the matter to the proper persons; and conversely, if an institution desired to know the present trend in regard to any particular feature of engineering education it can secure reactions from the different engineering schools through these representatives.

In the original recommendation presented to the Council for the establishment of the Institutional Division, it was clearly brought out that there were two different types of problems in which the members of the Society are vitally interested—those which have to do particularly with teaching and the individual, and those which have to do, to a greater extent, with administrative problems. It was recognized that every administrative problem was bound up with good teaching. To separate them would be impossible since the object of college administration should be the promotion of effective teaching.

The engineering colleges which are institutional members have been asked, through their presidents, to appoint official

representatives from the institutions to the Society. A striking fact brought out by an examination of the appointments is the number of these representatives who are elected by the engineering faculties. Thus they represent very distinctly, not only the administrative side of the institution, but particularly the faculty. If these representatives are to be elected by their faculties it will make the Institutional Division truly representative of the engineering faculties of the country. It is obvious that such an organization, while it could discuss numerous problems at its annual meetings, can make a careful study of but one or possibly two problems in a single year.

Under the direction of Dean C. C. Williams, a Vice-President of the Society and Chairman of the Institutional Division this year, this organization is looking to the study of a specific problem for which a small appropriation from the funds of the Board of Investigation and Coordination has been made. Details of this proposed investigation will be published very shortly.

The Institutional Division will now become an integral part of the Society and a vital factor in "developing, broadening and enriching engineering education."

REVIEW OF THE REPORT OF THE BOARD OF INVESTIGATION AND COORDINATION AS RELATED TO THE ENGINEERING SCHOOL AT THE UNIVERSITY OF NORTH CAROLINA.*

BY DEAN G. M. BRAUNE,

When you were invited by our President to hold your 1928 meeting in Chapel Hill it was my earnest and sincere desire that I should be entirely free from the responsibility of presenting any paper; I felt that my services would be of far greater value if directed towards the entertainment of our guests and assisting in providing for them a Southern welcome. Dean Bishop thought otherwise however, and he has placed my name on the program. Now, the title of this paper is somewhat misleading, in that it would indicate that I was going to review that comprehensive fact-finding report of the Board of Investigation and Coordination.

Far be it from me to assume any such great responsibility as the title of the paper would lead one to believe. I shall refer only briefly to certain points or suggestions that have been made by the Board, and about which some of us may entertain different opinions.

The fact-finding report has been so comprehensive, that probably everything pertaining to engineering education has been investigated and the facts have been tabulated, very admirably, in a series of convenient reports which will prove of invaluable benefit to those engaged in engineering education. Because of certain remarks that I may make, and which might be regarded as a criticism of the report, I wish to express the very highest praise of the excellent work that has been performed by the Board. The many facts concerning engineering education that have been gathered together justify to the highest degree the money that has been expended

* Presented at the 36th annual meeting of the S. P. E. E., University of North Carolina, June 27–28, 1928.

in making this investigation. However, certain important conclusions and suggestions that have been made by the Director and his Board could have been, I believe, forecast independently of the facts that have been assembled. The first preliminary report of the Director, for instance, is a very excellent philosophical dissertation on engineering education, but those of us who know Mr. Wickenden feel convinced that he is eminently capable of presenting this preliminary report without recourse to the vast knowledge assembled by the fact-finding committees.

The much debated question concerning the length of the curriculum has been settled, at least for the present, by the recommendation of the Board that the engineering schools adhere to the 4-year course. However, I do not believe that the facts as gathered could have been the determining factors in recommending a four year course rather than a five or six year course. A decision of this character depends somewhat on the training and the personal inclination of the Committee and probably could have been forecast in the early beginning of the investigation.

Our engineering faculty at the University of North Carolina has been debating for several years the question of extending our curriculum to five years. However, the decision to adhere to the four year course was not based on the recommendation of the Board, but was made because of certain practical reasons. The two chief reasons were: additional expense to the teaching budget, and a probable radical decrease in student attendance. However, our idea of adding an additional year to the curriculum was assuredly not to increase the technical content of the course but to provide a pre-engineering year for high school students who find great difficulty in adjusting themselves to the more rigid requirements in an engineering school as compared to the high school period. It was to be considered somewhat in the nature of a transition year for the entering high school students, with the provision of course that the pre-engineering students should be under the supervision and control of the engineering faculty. Incidentally the students would have received some

additional cultural training, but the controlling idea was to provide a transition period and also to improve greatly the selection of material for the engineering school. The advantages of a pre-engineering year as set forth above would apply more particularly to Southern institutions where the secondary education has not reached the higher level of instruction that would be found in many of the Eastern and Northern high schools. For these reasons, I believe the majority of our faculty was in favor of the pre-engineering year as judged from the standpoint of securing a more ideal engineering school; but because of the practical objections as stated above the faculty as a unit did not favor the change.

However, I do not believe that this question as to length of course has been finally settled, but that sometime in the not so distant future it will again be a lively point for discussion. From the practical standpoint of simply training students for specialized industries no doubt the shorter period is more advantageous, and probably this view point was given consideration by the Board members.

With reference to a uniform engineering curriculum the Board in its second report expresses the opinion that

"Defense of engineering education as a unified process should not be mistaken as a plea for uniformity. There is no inherent reason why all engineering colleges should be organized on the same plan or offer similar programs of studies. Standardized uniformity is sterile, but diversity makes for progress which is more often spread through experiment and example than imposed through mass movements." (Second Report, page 12.)

I agree wholly with these sentiments, but the statement has been somewhat nullified by the article on "Engineering Curriculum," by the Associate Director which was presented at the meeting in Maine and appeared in the September 1927 JOURNAL. I refer to that part of the paper under the caption, "Curriculum Revision," where a schematic curriculum is quite definitely outlined for a four year course. The author does emphasize very strongly that this curriculum as presented or suggested is not a recommendation of the Board

but merely an outline to stimulate discussion among the various faculties.

But nevertheless a number of faculties will surely accept this outline as a definite recommendation of the Board and attempt to design or revise their existing curricula to agree with the outline even to the decimal hours that are shown in the table. In other words, there will be a strong tendency towards a standardized curriculum among a large number of engineering schools, which is exactly contrary to the sentiments of the Report of the Board which have been quoted above. With all due respect to the good intentions of the author I believe it would have served the purpose better if the subject matter had been paraphrased without the introduction of the exact stipulation of the hours per week. As the matter now stands this curriculum will be regarded and accepted as a definite standard recommendation of the Board—that is, the design of the curriculum has reached its final stage, at least for a number of faculties.

The German and Austrian technical universities, and to some extent the Swiss engineering schools, have standard engineering curricula. In fact, one may attend the school at Dresden for one semester, transfer to Berlin for the second term, then to Stuttgart for the third, to Carlsruhe for the fourth, and back to Dresden for the fifth semester where, if the student desires he may present himself for his first examination, or Vor-prüfung. If he desires he may continue this alternation during the second stage of the curriculum. This standardization permits one to visit the various schools and attend lectures of the experts in their particular calling. It is evident, however, that such a plan is not adaptable to our American institutions.

Bulletin No. 12 of the Board of Investigation and Coordination presents a study of the cooperative method of education. It might be of interest to the Society to outline very briefly the method in vogue at the University of North Carolina. I wish to go on record that I am not a blind enthusiast on Cooperative Education. I can see the good advantages of

the system as well as certain disadvantages. To one who has spent a number of years in engineering practice, and who later in life enters the teaching field, it would appear self-evident to this person that there is a decided advantage for the student to spend part of his school period on outside engineering activities, performed under the partial guidance of an engineer-professor.

Our method in North Carolina is somewhat similar to the one formerly employed at Harvard, but later discontinued at that institution. The main difference between the two methods was that at Harvard the registration in the cooperative plan was voluntary, whereas at North Carolina it is compulsory for all students who are working towards a degree. It would be extremely difficult to operate on any other basis.

At the University of North Carolina the cooperative plan extends through the Junior year only, while the students of the freshman, sophomore, and senior years are full time resident students. Under this plan the student's participation in the University activities and his association with the general student body is curtailed to a very limited extent. The period of alternation is approximately of eight weeks duration. The objective of the method is to provide an opportunity for contact with the outside engineering activities during the school formative period, and to serve as a corrective measure for certain short comings that would not be apparent in the regular classroom work.

In order to illustrate the latter objective I will cite cases of two students that occurred within the past year.

Both of these students were excellent in their scholastic work, and had been elected to the honorary Phi Beta Kappa fraternity. One of the students was employed with a large corporation who demanded from the cooperating students the same loyalty and attention to duties as from their regular employees. During the first period of his employment, his services as shown by the report card of the superintendent were far from satisfactory, and the complaints were of such nature that they would not have been apparent in his regular

scholastic duties but could only have developed in connection with his outside work. The young man was advised about his shortcomings and told that the satisfactory performance of his duties while engaged on his outside work was equally as important as securing excellent scholastic grades. He showed himself amenable to suggestions and advice from his Dean and head of the department, and his later services with his cooperative firm were highly satisfactory. When questioning this young man concerning the greatest good that he had derived from his school work, he replied that the corrective measures employed during his cooperative training he considered of inestimable value in his future career.

The case of the second student was somewhat different. His report card also was unsatisfactory, but again the complaints were such that would not have developed in the regular classroom work. The young man was very much dissatisfied, and intimated that he would not return to his cooperative job. But after a number of discussions with the Dean and the head of his department he voluntarily took up his duties again and has shown a lively interest in his outside work and is performing his duties satisfactorily.

Now, for these two young men their cooperative training will have been of inestimable value for their future life work, and the corrective measures that were employed could not have been accomplished in the regular scholastic training. Other similar cases could be cited.

In the bulletin on Cooperative Education certain conclusions are given at the end of the report. When reading these from the standpoint of one who can see without prejudice both sides of the argument concerning the advantages and disadvantages of cooperative education, it appears to the speaker that the conclusions as stated are fair and unbiased and to some extent a reasonable endorsement of the cooperative system when applied with some sense of understanding.

In the opinion of the speaker it would have been better to have eliminated the pro and con arguments that were given in parallel columns, since these could have been changed *ad*

libertum depending upon the enthusiastic approval or the prejudicial attitude of the participants in the discussion.

To repeat again, I believe that the Board of Investigation and Coordination through its fact-finding committees has performed a most excellent service for engineering education, and for my part I consider these various reports an extremely valuable addition to my library.

SURVEYING, AN ORIENTATION AND MOTIVATION COURSE.

BY L. O. STEWART,

Assistant Professor of Civil Engineering, Iowa State College.

A recent investigation by the Society for The Promotion of Engineering Education in which several subjects of the civil engineering curriculum were ranked in the order of their importance by engineers suggests the thought that Surveying, which was placed at the top of the list, offers an opportunity for a real orientation and motivation course as well as a utilitarian course.

It will be agreed, no doubt, that surveying is of fundamental importance to all branches of civil engineering. Few projects can be initiated without some sort of a survey. The response to the Society's questionnaire corroborates such a statement. In this discussion the author would indicate how the proper utilization of these basic relationships may be used to motivate and energize the students' entire college course.

Surveying seems to be adapted admirably to the purpose at hand. What could be more interesting than the accounts of the work of the early surveyors of the public lands, their hardships and their rough outdoor life! Right there we are bringing into play some of the boy's (and the man's) fundamental instincts—his love of nature, his desire to emulate or hero worship, his combativeness, for those old time surveyors spent many hard days and sleepless nights awaiting the attacks of the Indians. And what young man can resist the romantic appeal of a railroad or highway survey in the tropics where the monkeys swing from tree to tree and chatter as they pass; or where vari-colored birds and beautiful flowers are a delight to the eye. Even a seemingly prosaic operation like the survey of a dusty highway becomes interesting if the student can be helped to visualize the completed road leading

on and on to new fields and vistas. Surveying, then offers a grand opportunity to direct the students' wandering thoughts into interesting channels.

But the interest while very important is not enough to make the course sufficient. The acts of an Oriental snake charmer or sword swallorer attract attention and hold one's interest for a time. Unless the acts are recognized as worthwhile and similar to situations that will be met later in life the useful effect will not be very large. Here is the challenge to the teacher of surveying. The work should be presented in such a way that the students will recognize the presentation as true to life and worthwhile. Here there is danger that one may fall into error. If a situation is to be true to life it must be offered and developed as a truly representative field problem exactly as it would be (and must be later) done under field conditions.

At this point the distinction and correlation between the theory and practice of surveying may be noted, for surveying is both an art and a science. The important consideration is that a good engineer or surveyor will not develop through a contemplation of trigonometry alone any more than he will from the mere manipulation of the transit or level. It is very true that the prospective engineer must understand his mathematics and know how to manipulate a transit. Those are his working tools. He should be led at once to the attack upon a real problem.

The instructor should exercise extreme care, therefore, in his use of a manual which gives certain operations to be performed—much like a cook's recipe book. Two defects of such a course should be noted: in the first place the important connection between an actual situation and the "set" problem is often missed entirely; and secondly, the instructor is losing an excellent opportunity for tying in the surveying work with a later course in the curriculum.

It would seem that the best plan to be followed by the instructor would be to present all of his material in the form of real problems. An example will make the meaning clearer.

In an ordinary farm survey the Surveyor is usually called to determine the lengths and bearings of all courses and, probably, the area. During that survey he will find it necessary to dodge obstacles on line, chain on offset lines, run random lines, chain on slopes, and the like. Those are fundamental operations which the student should understand. It seems likely that he will retain a more lasting impression of the random line, for example, if he meets it on such a problem than he will if given the "set" exercise of finding the distance between two points on an obstructed line. The difference is small, seemingly, but it is important.

Furthermore, the use of real problems offers an invaluable opportunity for reaching forward with the student's thoughts toward the later and more "meaty" courses of the curriculum. Much of his impatience during the first two years may be the fault of poor "forward connections." He feels that he is wasting his time. Surveying offers an ideal opportunity for keeping him busy with the present problem which he should be led to recognize as the kernel from which will grow his later courses. The design of a reservoir and dam in the senior year will be the culmination of a properly directed topographic survey in the sophomore year. The design of a bridge will follow a topographic and hydrographic survey in which attention was directed toward that later use.

It is true that we must not lose sight of the importance of manipulative skill. No one, scientist, artist, or artisan, can complete his work satisfactorily without mechanical skill in the use of his tools. But a proper educative process should emphasize the end and not the means to that end. In the case of Surveying the students will show a greater interest, and a correspondingly better progress, if they are faced with a real job at the beginning. The increased interest in the problem as a whole will lead them to a more intensive and efficient use of the instruments at hand.

REPORT ON FUTURE ORGANIZATION AND ACTIVITY.*

BY W. E. WICKENDEN,

Director of Investigation.

Foreword.—The Board of Investigation and Coordination inherited from an earlier Development Committee the problem "What can the Society do in a comprehensive way to develop, broaden and enrich engineering education." The Society had made a notable record of thirty years as an association of individuals but the limitations of individual effort were increasingly apparent. Its leaders sensed the need of increasing the resources of the Society and enlarging functions so as to promote more effectively the common interests of the colleges, stimulate them to a concerted attack upon their problems and bring them into more active relations with the engineering profession and the industries. The Development Committee, having found no ready made solution of this problem, recommended the establishment of the Board as an autonomous agency to work out experimentally a larger program for the Society.

In anticipation of a permanent plan, the Society adopted in principle at its Orono meeting † the recommendation of the Policy Committee and the Council for the creation of an Institutional Division, to concern itself with matters of primary interest to institutions or schools as such and to be coordinate with the Division of Individual Members, and for a central organization to continue and extend the activities which have been developed by the Board of Investigation and Coordination on an interim basis. It was proposed that this central organization when fully worked out should include a Board of Direction, a permanent staff organization, a joint liaison

* Presented at the Chapel Hill Convention, June, 1928.

† Minutes of the Orono Meeting, JOURNAL OF ENGINEERING EDUCATION, September 1927, pp. 91 and 101.

board with the engineering profession and industries and an endowed Foundation for Engineering Education. At the present stage of transition it seems appropriate to consider what permanent activities may grow out of the work of the Board and to suggest a more detailed plan of interrelation under which it is believed that the major divisions of the Society and a permanent staff organization can work most effectively.

I. GENERAL POLICY

Backgrounds.—Viewed in historical perspective, the present effort of the Society to extend its corporate functions is a normal evolutionary development and not a reversal of policy. The Society was a pioneer among the group of organizations which foster the special interests of the several divisions of higher education. Coming into the field early, in a day when education was still dominated by individual interests and traditions, it operated at the outset more largely as a medium of conference and personal association than as an agency of collective action. From 1893 on, and partly through the influence of the Society, engineering education began to outgrow the extreme individualism incidental to the pioneer period of its development. Since the turn of the century an increasing sense of need for a closer community of interest and effort has been reflected in the actions of the Society. In 1907 it invited a group of engineering societies to join with it in an extended inquiry into all branches of engineering education, which was later taken over by the Carnegie Foundation for the Advancement of Teaching. In 1923 the Society again sensed the need for collective effort and undertook to organize a comprehensive project of investigation and betterment which in this instance it carried out under its own direction with financial aid from the Carnegie Corporation and other donors. A further significant step was taken in 1927 when the Society instituted its Summer School as a major service activity. These steps testify to a rising desire and capacity among engineering educators for collective action.

The Present Task of the Society.—The past influence of the Society has been greatest in realms of individual responsibility, less in realms where institutions rather than individuals are primary units of action, and least in realms where the common interests of engineering education are involved with those of the educational system, the engineering profession and the industries. The present task is to bring these three types of activity into a good balance. It seems clear that the most urgent problems now before us lie largely outside the realms of individual effort. The town-meeting form of government by direct action of individual citizens suffices in small and self-contained communities, but fails in crowded and inter-related areas. If self-government in engineering education is to continue, as we hope, it needs more than a town-meeting form of organization.

The country is now well covered by engineering colleges and the need is not so much for more colleges or more easily accessible colleges as for better ones. The relation of these colleges within the educational system has passed beyond the stage of a purely local problem. We need to protect and possibly to readjust our relations within the general plan of university organization, also with the secondary schools, junior colleges, arts colleges, and colleges of business administration. We need to create a better balance between the more extended and the more intensive types of technological education. We need to define and strengthen our relations with the engineering profession, which can no longer maintain a casual attitude toward the sources from which it derives four-fifths of its recruitment. Changes in the attitude of industry are equally significant, as it substitutes the orderly processes of science for sporadic invention and turns away from the casual and wasteful process of natural selection to the deliberate recruitment and nurture of its future leadership.

Furthermore, it is evident that we must seek for major betterments in engineering education largely through better educational use of the early years after college where, if we are to work at all, we must share the field with the organized profession and the employing industries. The cooperative

programs for graduates recently organized by certain urban institutions indicate how large an area of initiative is open to individual colleges, but if the majority of our colleges which are remote from great industrial centers are to have any share in this movement for the extension of engineering education, as they should, they must do so largely through some collective relationship.

Means to These Ends.—The immediate task of the Society, to which the work of the Board has been an experimental approach, is to establish permanent agencies to foster the corporate as well as the individual interests of engineering education. For these purposes the Society needs larger resources than are provided by its current dues and more than occasional volunteer service. It seems clear that we have largely exhausted the possibilities of progress through the pooling of individual judgments. Fruitful action must be predicated on full knowledge of the relevant facts, must be guided by expert research and must have in view the interests of all the parties affected. It must proceed largely through controlled experimentation with a careful check-up and prompt reporting of the results. Progress may also be stimulated through frequent comparisons between our educational practices and those employed in other countries and through personal contact and reciprocity with their educators and engineers. In order to render these services to its constituency the Society needs the permanent services of a staff organization to direct its program of fact-finding, research and experimentation, to carry out its educational service activities and to maintain an active coordination of interests with other educational bodies, the organized profession and the industries. These services need to be closely integrated with the activities of the individual and institutional members of the Society.

II. PLAN OF ORGANIZATION

The interests and activities to be provided for fall naturally into four groups:

1. Interests in which the individual educator is the primary

unit of action and which may be promoted effectively by an association of individuals;

2. Interests in which the school or college is the primary unit of action and which may be promoted effectively by an association of institutions;

3. Interests which concern the Society at large and appertain to its administrative organization;

4. Interests in which the Society can be served effectively by a staff organization for research, service and coordination.

This analysis coincides with the plan of organization which the Society is now developing. The following sections are intended to suggest the general possibilities of this plan of organization and, in particular, to indicate how a staff organization can be coordinated with the other divisions of the Society.

The Division of Individual Members.—It would be in harmony with the past policy of the Society to keep this division as completely democratic as possible, by opening its membership on equal terms to all interested persons without distinction, by keeping its membership dues as low as the service given will permit and by multiplying local and regional units of organization as means of bringing the Society nearer to the interests of its scattered membership. There should be a forum for discussion, a journal for publication and frequent opportunities for personal fellowship. As far as practicable common and equal interests in realms where the initiative is primarily personal should be cultivated. Leadership should go with strength of personality, resourcefulness and solid experience, irrespective of rank. Emphasis should be given to the opportunity afforded by this division for young men to distinguish themselves before a jury of their seniors, their juniors and their peers. Applying these tests, the following appear to be the principal fields of interest and activity for this division:

The aims, ideals and philosophy of education;

The science and art of teaching;

Methods of measuring and ranking educational achievement;

Personal relations of teachers and students;
The professional status, welfare and ethics of teachers;
The objectives, content and order of specific subjects;
Departmental interests within curricula.

The more creative work of the division should be done through an active national committee organization. The writer strongly favors the plan of maintaining a moderate number of live committees, each charged with a fairly explicit project of research or problem of policy, rather than a large group of committees with purely permissive duties and for the most part inactive. The staff organization should be free to propose projects for committee work and committees should be free to enlist the aid of the staff in financing and executing their projects when special resources and services are required. In general, however, the division should function autonomously and should not look to the staff organization for the executive direction of its committee work.

In the appendix which follows there are included as an exhibit a list of suggested committees and a series of typical project assignments. The possible range of work is so wide that it would probably be desirable to make a limited selection for any single year's program.

The Division of Institutional Members.—This division should serve as an agency for collective action by the engineering colleges. Three broad functions appear to fall naturally within its scope:

1. Recognition of the status of schools and colleges of engineering through qualifying standards for institutional membership. While it may be assumed that the division of individual members will remain open on equal terms to all interested persons, an institutional division may properly be more selective. There appears to be no occasion or desire for a rigid standardization of engineering education or for any system of rating of schools on a scale of supposed excellence. On the other hand reasonable qualifying requirements for institutional membership would be justified as an aid in protecting educational standards, in exercising moral suasion on weak and marginal institutions, in deterring institutions from

entering the field of engineering education without adequate resources, and in guiding the public to discrimination between substantial institutions and those of dubious merit. There is still need for expansion in the broad realm of technological education, but it lies chiefly in other areas than that of professional preparation. The present engineering colleges have no claim to a patent of monopoly, but public interest would seem to favor some measure of "birth control" so long as other types of technological education remain underdeveloped. Whatever qualifying standards are set up, however, should not be so rigid as to hamper educational progress by stifling experimentation or other truly progressive movements.

As soon as joint action can be obtained, the qualifying standards of the institutional division should be coordinated with the standards of recognition employed by the national engineering societies in the administration of their membership regulations.

Without prejudging the issue in any way, it seems fitting to suggest that careful consideration should be given to the question of inclusion or recognition for other categories of institutions than engineering colleges, such as arts colleges with a concentration group in engineering sciences or with coordinated pre-engineering curricula, junior technical colleges, schools and colleges of industrial arts, non-collegiate technical institutes, corporation schools for engineering graduates, and the like.

2. Coordination of the interests of the engineering colleges, as a group, with other group units in the general educational system, including (1) preparatory institutions, (2) non-engineering colleges, (3) accrediting agencies, (4) state and federal boards and bureaus of education and (5) national educational organizations. There is an especially urgent need of better understanding with preparatory institutions, both secondary schools and junior colleges, and with the public educational authorities which control their curricula and standards, with a view to an effective adjustment between

preparatory and engineering studies. The present trends, incidental to a change of objectives from intellectual discipline to "adjustment to life situations," often operate adversely to engineering education. We have an interest in safeguarding certain preparatory subjects and in improving the effectiveness of educational guidance. There are many signs that a re-allocation of time and content between secondary and higher education is in process. Shall we accept the result passively, or exercise a due measure of influence on constructive lines? The present influence of engineering educators in these realms, acting as individuals, is fairly negligible, whereas the colleges might accomplish much through collective action, especially if the sympathetic cooperation of organizations representing the secondary schools and junior colleges can be enlisted in joint efforts. We need also to negotiate a basis of comity with the colleges of business administration, defining the responsibilities of each group in areas of common interest.

3. Inquiries and experimental projects relating to educational practices, and recommendations to the colleges based on the results. These projects should be selected from fields in which the institution, rather than the individual teacher, is the normal unit of action. Personnel practices dealing with admissions, orientation, remedial measures, record systems, occupational placements and the like are especially appropriate for cooperative inquiry and experimentation. The relations of engineering curricula to the general plan of university organization, the general structure and major group requirements of curricula, the forms of degrees for resident studies, the basis of award of professional degrees, matters of costs, fees, and financial resources, the qualifications to be required of teachers and the means of their development, and the coordination of college studies with subsequent education are highly appropriate realms for inquiry and recommendation by a division of institutional members.

The institutional division will presumably function through designated representatives of the member institutions. If thought advisable, provision may be made for subordinate

groupings by types of institution or by some regional plan. The principal activities, however, will probably be carried on through national committees. As in the plan suggested for the division of individual members, a system of explicit project assignments would probably assist in making the work of these committees effective. The staff organization should be free to suggest appropriate projects and the several committees should be free to enlist the aid of the staff in financing and executing their projects whenever special resources are required. In general, such projects as involve a continuing coordination between the engineering colleges and other educational, professional or industrial organizations should be handled as joint activities of the institutional division and the staff organization. In other respects the institutional division should function autonomously and should not look to the staff for the executive direction of its committee work.

The appendix which follows as an exhibit contains a suggested list of committees and a series of illustrative project assignments. The possible scope of the work is so great that it might be advisable to select a few of the more urgent activities for the first year and extend the work as the division gains headway.

The General Administrative Organization.—The normal functions of the president and treasurer are so well defined as to need no comment. It would seem appropriate to delegate the administrative headship of the individual and institutional divisions to respective vice-presidents, under each of whom autonomous organizations might be set up. The following administrative functions pertaining to the Secretary's office are well established:

Keeping records of the Society's membership;
Keeping records of the Society's activities;
Handling of routines in the election of members;
Editing and circulation of current publications;
Arrangements for general meetings;
Contacting with other organizations with which the Society has administrative relationships.

With the Society functioning through two coordinate divisions, a staff organization and local and regional subdivisions, it would seem to be advantageous to place the general coordination of its activities and the conduct of its routine general business under an executive board of manageable size, including the general officers and some members at large. The Council, including as at present all past presidents and representative groups of term members, would properly continue to discharge the legislative functions of the Society, receive and consider the reports of its officers, authorize its budget, audit its accounts, appoint nominating committees, confirm the election of members and fix the time and place of all general meetings. Subcommittees concerned with current administrative functions would normally be responsible to the executive board, while committees concerned with such collateral functions as the Lamme award might well report to the Council.

Staff Organization and Functions.—The principal functions of the staff organization would lie outside the realm of the executive direction of the Society and may be classified broadly as:

Research functions;
Service functions;
Liaison and coordination functions.

The plan of development adopted by the Society on the recommendation of the Policy Committee provides that the primary source of financial support for staff activities shall be an auxiliary Foundation for Engineering Education. While no formal measures have been taken, it has been suggested that the financial administration of the Foundation should be under separate fiduciary and executive bodies, the one to act as trustees for principal funds and the other to direct the expenditure of current funds. It has further been suggested that the executive body should include the executive board of the Society or representatives selected from its number, representatives of the national engineering societies, and possibly representatives of national industrial organizations.

There are several reasons which seem to make it advisable for the staff organization of the Society to be directly responsible to an executive board which would combine the present functions of the administrative officers and the Board of Investigation and Coordination. It is desirable to minimize executive machinery and avoid overlapping functions. The interrelations of the Foundation and the Society, as proposed in the above plan, make a clear and simple line of authority desirable. Furthermore, a close tying-in of the staff functions with those of the principal divisions of the Society would be facilitated by a common coordinating authority. It would be a distinct advantage to have the staff organization act on authority derived directly from the Society in all its relations with other organizations. The same principle holds for the authorization of such major service projects as the summer schools.

The staff organization should consist of a small, semipermanent nucleus for direction and service and of part-time and limited-term appointees on specific assignments. The staff should be responsible to a director named jointly by the Society and the Foundation. The auxiliary members should be drawn, for the most part, from the active teaching and administrative forces of the engineering colleges. This plan would serve equally to increase the contact between the staff and the active forces of the colleges and to broaden the contacts and experience of men drawn for part-time or temporary service from teaching ranks.

The activities of the staff would be partly autonomous and partly in active cooperation with committees of the major divisions of the Society, subject to the review of plans and budgets and their approval by a general executive board. It would be a large part of the duty of the staff to enlist the cooperation of colleges, educational organizations and foundations, professional societies and industries in the support and conduct of joint projects of research and betterment relating to engineering education. To perform these functions effectively the staff should have assured funds to cover all

overhead expense, all routine services, and, in addition, a substantial part of the expense of its major research and service functions. These conditions are necessary for long-range planning and to enable the staff to assume the costs and risks of initiative in proposing cooperative projects to colleges, professional societies and industrial organizations on a basis of fair equality. Experience has plainly shown the difficulty of raising overhead expenses and general funds through current contributions, whereas it has been possible to enlist schools and other agencies in cooperative projects in which they have a direct interest on the basis of hour for hour of service and dollar for dollar of expense.

It is recognized that adequate support for staff services is beyond the capacity of the Society to provide through current dues. Such funds as the colleges might provide can be used better for local participation in research and betterment projects than for the overhead expense of a staff organization. While it is necessary to seek a term grant or an endowment, the revenue from this source may properly be somewhat less than the projected scale of expenditure, the remainder to be obtained by enlisting the cooperation and support of other agencies. It is highly desirable that all the research and betterment projects fostered by the Society shall pass the fairly severe test of definiteness of aim and promise of value which is entailed in enlisting such cooperation and support. This test should apply equally to all projects proposed to the staff by the committees of the Society. A fair degree of competition between committees for material aid and service from the staff organization might be a wholesome stimulant.

The possible scope of the research and service projects which might be undertaken by a staff organization is so wide that it has seemed best to outline a suggested program for the early future as an exhibit in the appendix, rather than to expand the subject in the report itself. A single item may be selected for special comment. It is highly desirable to place the Summer School for Engineering Teachers on a permanent basis as a major service function of the Society. The sessions of the

school afford a notable opportunity for active teachers of engineering and related sciences and for experts in educational methods to collaborate in attacking the problems of teaching and in mapping out cooperative projects of inquiry and experimentation to be followed up as continuation activities. It seems expedient to keep the administrative handling of the Summer School and related projects in the hands of one member of the staff, in order that there may be continuity of policy, long-range planning, enlistment of cooperation from other bodies, and effective follow-up of the continuation projects. It is highly desirable, however, that there should be a close link between this staff activity and the Society's membership. One way to accomplish this end would be to name a departmental committee for each subject on which a session of the Summer School is held to advise with the staff on advance arrangements and to cooperate actively with the staff in carrying on the continuation activities. Departmental committees should be encouraged to propose to the staff that sessions of the School be held in their respective fields and to canvass the preliminary work which may be needed in advance. Actual decisions as to the sessions to be held from year to year should be made by the executive board of the Society, on recommendation from the staff.

The staff organization should be looked to for the coordination of the interests of the Society with those of other educational bodies and of professional and industrial bodies wherever a functional rather than a purely administrative relationship is involved. For example, any research projects on student personnel problems which the Society may undertake should be coordinated with the related projects of the American Council on Education through the staff organization, while relations incidental to the membership of the Society in the Council should pass through the administrative organization.

III. CONCLUSION

The desired betterments in engineering education can not be achieved through any swift revolution, but must come

through gradual evolutionary processes. The problem is to accelerate these processes and to bring them under a due measure of control. The work which the Society proposes can be made effective only through *a wide distribution of initiative combined with centralized cooperation.* This principle gives the key to the relations which should exist between the staff, the general divisions of the Society and its individual and institutional membership. Scattered and intermittent effort in the absence of broad vision and comprehensive policy will inevitably limit progress to the realm of details. Under ideal conditions readjustments in educational practices would anticipate changes in educational needs, rather than follow them tardily and imperfectly. This ideal is frankly Utopian, yet it is one toward which we should press as closely as we may. In doing so we shall need to strike a fine balance between collective effort, which at one extreme hardens into a deadening bureaucracy, and individual effort which disintegrates into chaos at the other. Michael Pupin, a distinguished engineering educator turned philosopher in his mellower years, has pointed the way to the middle course in his suggestive phrase "creative coordination," which would serve the Society as an excellent motto for its coat of arms.

APPENDIX

SUGGESTED COMMITTEES AND TYPICAL ASSIGNMENTS

I. Administration

Committee	Function or Assignment
Executive Board	To supervise and coordinate the activities of the several divisions of the Society.
Sub-committees on:	
Publications	
Meetings	
Sections and Branches	
Finance and Budget	
Staff Activities	

Council	Legislative action and supervision of elections.
Policy Committee Committee on Lamme Medal Award Nominating Committee	

II. Division of Individual Members

Committee	Function or Typical Assignment
Membership	To promote membership among individuals.
Aeronautics	To make a study of prospective occupational requirements and educational needs.
Agricultural Engineering Architectural Engineering Chemical Engineering Chemistry Civil Engineering	
Drawing and Descriptive Geometry	To make a study of time economy in learning selected phases of the subject.
Economics and Engineering Economy	To make a study, with the cooperation of the staff, of the uses of case materials in teaching, their sources and methods for their collection and distribution.
Electrical Engineering	To carry out, in cooperation with the staff, a cooperative trial of a comprehensive examination.
English	

History and Government	To cooperate with the staff in a project for the preparation of a treatise to set forth the influence of scientific discovery and technological advance on modern history and social institutions.
Industrial Engineering	
Industrial Relations	To make a study, with the cooperation of the staff, of the materials appropriate for teaching this subject to engineering students.
Materials of Engineering	
Mathematics	To make an inventory, with the cooperation of the staff, of the usage of the subject in the upper years of engineering curricula and in current engineering practice.
Mechanical Engineering	To cooperate with the staff in the advance planning of a session of the Summer School and continuation projects.
Mechanics	To carry on the continuation projects of the mechanics sessions of the Summer School.
Metallurgy	
Mining Engineering	
Modern Languages	
Physics	To carry on the continuation projects of the physics session of the Summer School.
Professional Status and	To make a study of the pro-

Welfare of Teachers	fessional practice privileges of engineering teachers.
Technical Nomenclature	To continue the work of the present committee.

III. Division of Institutional Members

Committee	Function or Typical Assignment
Institutional Membership	To propose regulations to govern the admission of institutional members: to consider what categories of membership, if any, are desirable; to seek coordination of accrediting regulations with national engineering societies; and to recommend action on applications from institutions.
Relations with Secondary Schools	To enlist cooperation of secondary schools through a joint committee to study the ability of the secondary schools to offer the preparatory studies which lead up to engineering; to advise on standards of achievement and methods of testing as a basis of admission by certificate; and to propose methods whereby deficits in preparatory education may be made up.
Sub-committee on Relations with Technical High Schools	To cooperate in a joint committee on coordination of curricula and on advance

	credits for shop practice, drawing, etc.
Relations with Non-Engineering colleges:	To coordinate the work of sub-committees:
a. Sub-committee on Relations with Junior Colleges	To enlist the cooperation of junior colleges through a joint committee to study pre-engineering curricula for junior colleges and transfers of credits.
b. Sub-committee on Relations with Arts Colleges	To enlist the cooperation of the arts colleges through a joint committee to propose a basis of transfer of credits and of admission to advanced standing in engineering curricula.
c. Sub-committee on Relations with Colleges of Business	To enlist the cooperation of the colleges of business administration in a joint committee to propose delimitations of responsibility in realms of joint interest to the two types of institutions.
Personal Practices:	To coordinate the work of sub-committees:
a. Sub-committee on Admissions	To review methods of selection or classification of entering students according to aptitudes or prospects of survival in college and to initiate cooperative experimentation in search of betterments.
b. Sub-committee on Orientation and Student Adjustment	To make a study of methods of orientation and personnel supervision for engineering freshmen.

c. Sub-committee on Personnel Records	To make studies and recommendations on personnel record systems.
d. Sub-committee on Employment and Placement	To make a study of the placement of prospective graduates and to propose methods of procedure to employment representatives.
Curricula	To make a study of the practicability of introducing a dual scheme of functional options, one primarily technical and the other giving more emphasis to matters of economy and management, in all major professional curricula.
Degree Practices	To recommend a policy concerning the forms of degrees appropriate for work done in residence, both undergraduate and post-graduate; to enlist the co-operation of the national engineering societies in recommending a basis of award of professional degrees under joint sanctions.
Costs and Fees	To study, with staff and actuarial assistance, the practicability of making tuition charges correspond more closely to actual costs of instruction through a form of deferred annuity payments.
Post-graduate and Post-Scholastic Education	To consider how, under present conditions, the contin-

	uation of systematic education during the early years after graduation may best be promoted and the part of the colleges therein.
Qualifications and Development of Teachers	To consider what academic qualifications and what professional experience and credentials should normally be required for full-time appointments.
Research	To consider how the industries and the colleges may best cooperate in the development of the research activities of the colleges.

IV. Staff Organization

The following projects are either in process or are under consideration for the early future:

- The Summer School for Engineering Teachers and continuation projects
  - Electrical Engineering Session, 1928
  - Physics Session, 1928
  - Mechanical Engineering Session, 1929
- Investigation of non-collegiate engineering education
  - Industrial requirements
  - Educational practices abroad
  - Present educational practices and results in America
- Investigation of instruction in shop practice and industrial technology
- Investigation of deferred tuition payments under an annuity contract
- Investigation of methods of selection or guidance of entering students
- Investigation of facilities and methods for extending engineering education during the early years of practice

Inventory of usage of higher mathematics in engineering curricula and practice

Preparation of a manual of information on engineering education and the engineering profession for teachers of occupations, vocational counsellors, etc.

Preparation of a treatise on the influence of scientific discovery and technological advance on modern history and social institutions

Preparation of case materials on engineering economy

Publication of monographs on educational principles and methods.

DISCUSSION.

Dean Hughes: Mr. Chairman and Gentlemen, as your chairman has said, I did not get this paper until a few hours ago, and I am somewhat overwhelmed by the large number of important suggestions that have been made. They touch at the very root of our engineering educational policy and practice.

The first thought that came to me as I read this paper was, Who would have time to do the work of the Institutional Committee if such a scheme were attempted; for it is so far-reaching and extensive as to raise both obstacles and objections.

Institutions and professors are both highly individual, which is a most desirable situation; and while there is much that is common in our problems, there are many policies and practices which have to be determined by local conditions. When such a sweeping project is proposed, the question is automatically raised as to whether any general agreement upon these vital matters can be had in committee, and, if so, how effectively can any such agreements be carried out. The Board has done admirable work in collecting facts, in pointing out our weaknesses or our strength, and then leaving intiative to the schools. This, I think, is as far as we should go as a society.

Consider the proposition about institutional membership. All executive officers have serious difficulties in the evaluation

of the previous studies of students transferring from other engineering colleges, and from arts colleges; and likewise in comparing institutions. You must be brave, and you will run the risk of hard feelings, if you tell a student that his previous course of study is not as satisfactory from your standpoint as if he had taken it in your institution; and yet in many cases that is true. The chairman of such a committee would have a turbulent existence. Certain professional schools, it is true, do limit their admission to graduates who rank in the upper quarter, or third or what not, of the graduates of "selected colleges." Have you tried to get their lists? Certain educational foundations have classified colleges and professional schools to the betterment of education in general; but it has been a trying process. I doubt most seriously whether this society can classify the engineering schools of this country without running the risk of doing more harm than good; we may however suggest a minimum requirement for the first degree in engineering.

The second suggestion seems to me of relatively small importance in the large; for I have knowledge of the content of secondary-school programs in both public and private schools of a great variety in widely scattered places, and have had students from such schools. There must, of course, be real grounds for such fears; or they would not be mentioned. Such conditions, when they exist, should be handled locally. A committee can do little beyond saying to the high school principals that boys planning to study engineering must have a certain preparation in mathematics. I strongly favor as broad a training as possible in literature, history, science, language, and mathematics, as a basis for the study of engineering; but I disapprove of the many fads that now encumber the instruction in secondary schools.

One of the most important problems of the engineering colleges is to arrange for a facile, flexible and fair means of transfer from arts colleges to engineering colleges and from one engineering college to another, both in the undergraduate and in the graduate stage. It is logical, and, from the standpoint of keeping down the age of graduation for those engineers

who wish to have a college course, important, that graduates of arts colleges should be able to complete the requirements for the first engineering degree in two years after college. It should also be possible to transfer to an engineering college after two or three years in an arts college, or after graduation from a junior college, on terms that are less costly of time than present practice commonly permits. Several factors that affect this problem may be worthy of brief consideration.

Graduates of arts colleges frequently enter engineering colleges with readily avoidable deficiencies that either overcrowd their schedule or needlessly lengthen their course of study. A college graduate of good average ability should be able to enter the junior class of an engineering college without insurmountable difficulties if he has had in college six semester class-room hours (with the necessary additional work in the laboratory) each in physics, chemistry, drawing, economics, and twelve hours of mathematics, at least six of which are the differential and integral calculus, and in special cases additional chemistry or physics, mathematics, geology, or other science. The requisite preparatory subjects can usually be taken in college without interfering in the least with the objects of a liberal education. Too often teachers in the arts colleges are not well informed of the real preparation required for the engineering colleges. Moreover, the engineering colleges are prone to overrate minor deficiencies, and require graduates to make up unimportant details, which might be well waived for men of such maturity and extensive education. Moreover, it is at present well nigh impossible to evaluate a transfer student's previous courses of study with sufficient accuracy to give him his proper standing. Long experience has convinced me that standards of teaching and marking vary greatly not only as among institutions, but also within one institution. To require examinations in vital subjects would be resented by applicants, and under the prevailing practice that each teacher makes and marks his own examinations, such a test would usually be untrustworthy as a guide to ranking. We have recently had in our school an enlightening experience on examinations. For four consecutive years

we have offered a competitive examination for a scholarship of one thousand dollars, open to seniors about to graduate with honors from an arts college (engineering students and members of Harvard University not eligible). The paper was made up, and the books were graded by a committee of our professors representing in their first degrees five different colleges. The subject matter covered two years of college mathematics, and one year of college physics. The examination was taken in each case at the college where each senior was then enrolled, and under the rules there in force. The results were both unexpected and disheartening. In all about eighty papers were returned and graded; only six papers in four years were good enough to be considered for the prize. In one year there were none of sufficient merit, and there were many total failures. Yet every one of these applicants would be welcomed by any engineering school and with few exceptions would doubtless have attained high rank in their engineering studies.

There is no doubt that the business schools are getting many students that we, as teachers of engineering, think should come to us; it is by no means certain that some of our own registrants might be enrolled in business schools without detriment to us, and perhaps to their own advantage. As long as our engineering graduates continue to compete so successfully for so many executive positions in industry, we should not be unduly concerned. On the other hand, a better mutual understanding and more cooperation would doubtless lead to better instruction in both types of institutions.

We will all agree, I am sure, that the most important question of all is to find ways and means to secure, to develop and especially to keep good teachers. I have gradually come to the conclusion that the money competition of industry is not the only important source of our difficulties. Many of our teachers are so hopelessly overworked that they can not do the quality of work for which they are fitted, nor develop their talents. The remedy may well lie in the simplification of programs, and in the limitation of offerings to what we can afford to provide instead of attempting to give everything con-

ceivable, at the expense of the teacher's health, happiness and development.

This paper is a most admirable summary of what we ought to do, and I approve of most of it heartily, but I do not see who will have time to do the work.

A. A. Potter: As Dr. W. E. Wickenden has so well brought out in his "Report on Future Organization and Activity," the Society for the Promotion of Engineering Education has in the past exerted its influence mainly through individual responsibility. The Institutional Delegates, though appointed by the Presidents of institutions at the request of the Secretary of the Society and decorated with special ribbons at registration, actually had no opportunity to contribute to the broader problems in engineering education through collective action. The status of the institutional delegate in the S. P. E. E. is in this respect very different from that in an association of institutions such as the Association of Land Grant Colleges and Universities, where the deliberations and actions of the institutional delegates are taken very seriously by the institutions they represent.

The proposed functions of institutional members as outlined by Dr. Wickenden should result in fixing more definitely the status and influence of institutional delegates. The proposed functions which do not interfere with the individuality of institutions include:

1. *Fixing Qualifying Standards for Institutional Membership.*—The architects have demonstrated the value of this procedure in protecting standards and in encouraging weaker institutions to improve the quality of their product. There are too many institutions in the U. S. A. which claim to give higher education in engineering without sufficient resources. Institutional membership in the S. P. E. E. should indicate recognized standards and should be determined by methods similar to those now in use by the North Central Association of Colleges and Secondary Schools and by other recognized accrediting agencies. It may be found desirable to have several grades or types of institutional membership to include institutions other than engineering colleges.

2. *Coordination of the Interests of Engineering Colleges as a Group with Other Types of Institutions, Accrediting Agencies, Public Educational Boards and National Educational Institutions.*—To attract to engineering colleges well prepared secondary school graduates and superior students from non-engineering colleges, the importance of the above mentioned contacts is self-evident. The institutional members acting collectively can exert a very definite and beneficial influence upon the quality of the preparation of high school graduates who are entering engineering colleges. Coordinating the interests of all types of institutions giving technical instruction, collegiate and non-collegiate, will also result in definite benefits to all concerned.

3. A study of institutional practices and recommendations with reference to personnel problems, curricula relations, forms of degrees, costs, fees, methods of recruiting teachers, and similar problems is within the province of the institutional division and only indirectly concern the individual teacher. The findings of such studies will not be binding upon the institutions, but will prove helpful to engineering education.

The whole problem of recruitment of teachers for engineering colleges should be considered by the institutional division at an early date. Should we adopt the practice common in European countries and advertise our vacancies in the technical or even in the daily news or should we continue our present system which is particularly inadequate in connection with the recruitment of teachers for the lower ranks?

The above mentioned functions of the institutional members should be carried on to supplement the proposed division of individual members and the general administrative organization; these divisions should be coordinated by a staff organization for research and service in order to insure full protection to the corporate as well as individual interests of engineering education.

REPORT OF COMMITTEE ON POLICY ON "REPORT ON FUTURE ORGANIZATION AND ACTIVITY."

The Board of Investigation and Coordination has referred to the Committee on Policy a report of the Director of Investigation to the Board on "Future Organization and Activity," which in line with the recommendations of this committee as adopted in June, 1928, proposes in detail developments in activity and modifications of organization. In this suggestive and valuable report two features stand out, first the clearer separation and definition of the functions of the Institutional Division on the one hand, and the Institutional membership on the other hand; and second, the merging of the functions of the present Executive Committee of the Society and the function of the type performed by the present Board of Investigation and Coordination into the function of a single enlarged executive committee of the Society.

On the subject of the first feature of this report the Committee on Policy recommends that every encouragement be given by the Council to the organization of the Institutional Division for the effective performance of its special functions in the Society.

On the subject of the second feature of the report of the Director of Investigations, namely the suggested merging of the functions of the present Executive Committee and of the present Board of Investigation and Coordination into the functions of a single enlarged executive committee, the Committee on Policy is not prepared to recommend action at present, but does recommend that this question of the central organization and definition of functions be a subject of study through the next year by the Committee on Policy if continued. The Committee considers that such a study is of great importance in view of the fact that the present Board of Investigation and Coordination may have completed its work by the end of 1929.

OUR DEBT TO THE ELECTRICIANS OF THE NINETEENTH CENTURY.*

By Henry Crew,

Professor of Physics, Northwestern University.

PART I.

Mr. Chairman and fellow-students:

The time has almost arrived when it is bad form to address a group of physicists on any topic which does not deal either with the structure of matter or with the nature of radiation —the two outstanding problems of modern physics. Some of my younger colleagues, in their enthusiasm for the physics of the present moment, remind me of a character which Balzac introduces into one of his stories, a young woman—a member of the demi-monde—for whom the future was the time for her next meal, and eternity a time which is as far off as tomorrow. Nevertheless I am inviting your attention to the achievements of a century which lies wholly in the past. My apology for this course is three-fold: the first is that present-day problems are receiving admirable and ample treatment at the hands of my colleagues; secondly, it is only by becoming aware of the collective achievements of mankind that one can fully realize the possibility of greater things to come, and in the effort to reach these greater things lies not only the best of sports, but also our best protection against the waste of life and energy in the petty quarrels of men and nations; and thirdly, it is only by looking backward that a teacher can realize the continual change of view-point which has taken place in his own subject during recent years and only in this way does he fully grasp the unity of modern physics.

It is now less than a year since men of science from all parts of the world were making a pilgrimage to Lake Como in honor of the man who, in the year 1800, described the earliest device for producing electricity of low voltage and for deriving it

* Two lectures delivered before the Physics Session of the Summer School for Engineering Teachers, Cambridge, Massachusetts, July 13 and 14, 1928.

from an almost infinite variety of substances. It was also in the last year of the nineteenth century that Sir Joseph Thomson,* in a paper read before the Dover Meeting of the British Association and published in the *Philosophical Magazine* for December of that year, convinced the world that the electron is a constituent of all kinds of matter. The nineteenth century is therefore bounded by two striking electrical achievements, the invention of the Voltaic cell and the discovery of the electron. It is to the electrical discoveries of this period to which your attention is directed.

The backwardness of electrical science at the beginning of the nineteenth century is difficult for us to realize. The "Principia" was then more than a century old. The "Mécanique Analytique" of Lagrange had been off the press twelve years. The first two volumes of the "Mécanique Celeste" had appeared in 1799. Poisson was at that time the brilliant student of Lagrange and Laplace at the École Polytechnique; mechanics was far advanced and was on solid ground. Chemistry had developed as far as it could go without the atomic theory, the birth of which was still eight years in the future. But optics and electricity were far behind; the corpuscular theory of Newton still held the field. At the opening of the century, Thomas Young (1773–1829) had just completed his course at Cambridge and was settling in London as a practicing physician; Fresnel (1788–1827) was a boy of twelve just getting ready to enter the École Polytechnique. Electrical science was still limited to electrostatics; and was in nearly the condition in which Gilbert, Gray, DuFay (1698–1739), Franklin (1706–1790), Coulomb (1736–1806) and Cavendish (1731–1810) had left it. Bennet (1750–1799) the inventor of the gold leaf electroscope had been in his grave only a year; Galvani (1737–1798) had died the year before Bennet.

The Voltaic Cell.—It was just at this period that Volta, the quiet, modest, Italian scholar, large of frame, and capable of prolonged thought, had inherited the problem of Galvani. Philosophically and poetically inclined, Volta had that rare

* J. J. Thomson, "On the Masses of the Ions in Gases at Low Pressures," *Phil. Mag.*, 48, 547–567 (1899).

quality which always marks the productive scholar, the habit of putting to himself questions and of not remaining satisfied until he has obtained an answer in the simplest possible terms. The final solution at which he arrived in his study of the ten-year-old Galvani phenomenon—the twitching of the frog's legs—was sent to the Royal Society of London under date of March 20, 1800. This brief communication of Volta's, in which the essence of the matter is seen to be two metallic conductors and an electrolyte, had several far reaching effects.

Firstly, it put an end to the idea of "animal electricity" as used by Galvani; and it started that long series of experiments to prove the identity of electricities from whatever source obtained—a series extending over 88 years and ending only with the experiment of Rowland and Hutchinson * which established beyond doubt the magnetic effect of a moving electric charge.

Secondly, the Voltaic cell, in substituting steady for transient currents, gave the investigator just the same sort of advantage which the spectroscope of Lockyer and Janssen offered to the astronomer whose previous study of the chromosphere was limited to the few fleeting moments of a solar eclipse. Electric current effects could now be studied at leisure.

Thirdly, this simple device of Volta's (most easily presented to the new student as a drop of sulphuric acid connecting a bit of zinc and a bit of copper through a galvanometer) has for more than a century aroused the curiosity of every serious student of physics as to the source and location of its E.M.F. Volta really made two discoveries: the first, in 1800, was a mode of producing steady electric currents; the second, in 1801, was the fact that a piece of copper brought into contact with a piece of zinc will assume a different potential from that of the zinc. Each of these phenomena is involved in every Voltaic cell. Many explanations have been offered. The three following are perhaps typical.

(i) Kelvin (*Phil. Mag.*, Dec. 1851) early gave a theory of the cell in terms of the heat of combustion which, as you all know, makes the E.M.F. equal to the heat developed when

* H. A. Rowland and C. T. Hutchinson, "On the Electromagnetic Effect of Convection Currents," *Phil. Mag.*, 27, 445–460 (1889).

one equivalent of an electrode is transformed; or

$$E = \frac{2JH}{9654} \text{ in C. G. S. units}$$

for a divalent metal; to this expression Helmholtz added a term

$$T\frac{dE}{dT}$$

to correct for change of temperature, so that

$$E = \frac{H}{46000} + T\frac{dE}{dT}, \text{ in volts,}$$

where H is the amount of heat, in calories, liberated by the passage of 96540 coulombs through the cell. If now, in addition to the law of conservation of energy, we bring in the law of the dissipation of energy, we have a fairly complete explanation of the cell.

(ii) Then there is another energy-theory of the cell due to Nernst in which the metal passes into the electrolyte as a stream of charged ions. Nernst * supposes a metal to possess a definite solution pressure analogous to ordinary osmotic pressure. This solution pressure between metal and electrolyte is responsible for a difference of potential at each of the metal/liquid junctions, and when once established, all one has to do in order to obtain a current is to connect the two metal electrodes by a wire. Each of these theories appears to rest on an experimental basis, each gives very nearly the correct value for the Daniell cell and the two are self-consistent; but one is still left wondering whether we have anything other than a mathematical description of the cell; and one is reminded of Bertrand Russell's † remark that "Physics is mathematical not because we know so much about the physical world; but because we know so little; it is only the mathematical properties that we can discover."

(iii) If now, for the sake of perspective, one passes for just a moment, beyond the limits of our chosen century, he finds that Professor Millikan ‡ has proved the "stopping po-

* W. Nernst, *Zeitschr. Phys. Chem.*, 4, 129 (1889).

† B. Russell, "Outline of Philosophy," p. 163.

‡ R. A. Millikan, *Phys. Review*, 18, 236 (1921); *Phys. Review*, 7, 25 (1916).

tentials'' to be the same for all metals; and has established the following expression for the E.M.F. of contact between two metals.

$$\text{Contact E.M.F.} = \frac{h\nu_{0B} - h\nu_{0A} - (W_{1B} - W_{1A})}{e}$$

$$= \frac{h}{e}(\nu_{0B} - \nu_{0A}) - \left(\frac{W_{1B} - W_{1A}}{e}\right),$$

where h = Planck's constant,

ν_{0A} = frequency of light which will just remove an electron from first metal, without giving it any velocity,

ν_{0B} = frequency of light which will just remove an electron from second metal, without giving it any velocity,

W_{1A} = work necessary to just detach an electron from its parent atom in first metal,

W_{1B} = work necessary to just detach an electron from its parent atom in second metal.

This equation flows immediately from the point of view which makes the E.M.F. of contact equal to the difference of work required to detach a free or conducting electron from the two metals in succession. In other words,

$$\text{Contact E.M.F.} = \frac{W_{2B} - W_{2A}}{e},$$

where W_{2A} and W_{2B} represent the work required to just detach a free electron from the surfaces of the respective metals. The natural attraction of matter for an electron which is here assumed accords with the following experiment from the chemical laboratory. One dips a bit of zinc into a solution of copper sulphate and observes that metallic copper is at once laid down on the zinc, a phenomenon which he interprets to mean that the zinc ions (Zn^{++}) have a greater tendency than the copper ions (Cu^{++}) to go into solution and remain there; or that the copper ion has a stronger attraction for the electrons in the zinc than has the zinc ion.

Or, as Professor E. H. Hall * puts the matter, the problem

* E. H. Hall, ''Conditions of Electrical Equilibrium at Boundary Surfaces; Volta Effect,'' *Proc. Nat. Acad. Sci.*, 11, 111 (1925).

of the Voltaic cell reduces itself to a "contest between the ions of the two metals for the possession of electrons."

Whether in any one of these theories, each of which is honeycombed with assumptions, we have a view which puts the physics of the primary cell in a manner sufficiently clear for presentation to undergraduates, I am still somewhat doubtful. However, I am not forgetting that the lack of clearness may be confined entirely to my own mind.

If the theory of the cell is to be presented to undergraduates at all, I am inclined to think that the analogue recently presented by Professor Corbino (*Phil. Mag.*, 4, 436, 1927) of Rome will be found a valuable aid.

Standing upon the photoelectric and thermionic effects as a foundation, he starts with the following expression for the Volta contact E.M.F. which he denotes by V.

$$V = \frac{W_1 - W_2}{e} + T\frac{dV}{dT},$$

where W_1 and W_2 denote the respective work functions of the two metals, and the last term in the second member is the well known expression for the Peltier effect. Corbino apparently considers the establishment of this equation as the easiest part of the whole problem and at once proceeds to consider the physics of the Daniell cell.

The net process in this cell is described as one zinc ion going into solution, two electrons thus set free passing the Cu-Zn junction, one copper ion going out of solution, meeting and binding the two electrons, which have just gone around the metallic part of the circuit, and finally the $-SO_4$ radical left intact in the electrolyte.

The Analogue.—All the main features of this cell, Corbino finds in a model constructed as follows. Take a glass tube having the shape of an anchor-ring; insert at any point in the tube a movable piston, impermeable and frictionless; insert at another point in the tube a fixed semipermeable membrane. These two partitions will divide the anchor-ring into two compartments, A and B. Fill each compartment with a saturated solution of a salt—the two salts being different and each having crystals present in excess. Remembering now

that a Daniell cell consists of a pair of metals each dipped into a solution of one of its salts the analogy will be clear if

(i) the conduction electrons of the cell are represented, in the model, by the molecules of the solvent; that is, by the molecules of water;

(ii) each metal of the cell is represented by the saturated solution in the model;

iii) the electrolyte of the cell is represented in the model by the solid phase of salt solution;

(iv) as a metal may gain or lose electrons, only by contact with other metal; so in the model, a solution may gain or lose *water* only by contact with another solution through the semipermeable membrane;

(v) as a *metal* may gain or lose metallic ions only through the eletrolyte, so in the model, the *solution* may gain or lose molecules of the dissolved body only through contact with the solid phase of the latter.

(vi) The motion of the electrons through the bimetallic junction is represented in the model by the motion of the water through the semipermeable membrane.

(vii) The difference between the attractions which copper and zinc exhibit for electrons becomes, in the model, the difference of attractions of the two solutions for water, which we call osmotic pressure. In other words, the difference in potential at the Zn-Cu junction is represented by the difference in hydrostatic pressure between the compartments *A* and *B*. In brief, the semipermeable wall tends to maintain the difference of hydrostatic pressures; while the motion of the piston tends to destroy it.

(viii) Finally, if in the model, one assumes the dissolving of the salt to be an exothermic process, he has in the heat thus developed the analogue of the heat developed in the Daniell cell.

If anyone is inclined to think that this model does not get us very far, I am inclined to agree with him; if one holds that it merely substitutes the mystery of osmotic pressure for the equally mysterious contact E.M.F., I must assent. On the other hand, the behavior of the two systems are strikingly alike; the model is based on chemical laws; it does not rely

upon electrical principles; and moreover it makes no pretense to be an explanation; it is merely an analogy which the teacher of physics may find helpful.

The last word has not yet been said concerning the Voltaic cell. You may, indeed, have noticed that the topic which Professor A. W. Porter, sectional president of the British Association, has chosen for his address on the 10th of September next at Glasgow is "The Volta-effect; Old and New Evidence."

If Volta is to be considered as the first of our outstanding creditors in the nineteenth century, the next will, I think, by general consent, be Oersted. But the twenty years which intervene between these two men were not years of idleness. Within five or six weeks after Volta's great paper had reached London, and even before it was presented to the Royal Society, Nicholson and Carlisle had electrolyzed water, thus producing a phenomenon which was the converse of Cavendish's * synthesis of water from oxygen and hydrogen, sixteen years earlier. Then follows a great maze of phenomena such as the various reactions at the electrodes, all of which seem simple enough now; but was then tremendously complex. Early in 1802, Brugnatelli, a colleague of Volta's at Pavia, had demonstrated the practicability of gold and silver plating by means of electro-deposition. In the same year, J. W. Ritter (1776–1810) had taken a pile of discs of *one* kind of metal, each separated from its neighbors by moistened cloth and had shown that he could transform this pile into a Voltaic battery by merely passing an electric current through it. Here, of course, was the germ of the modern storage cell.

In his Bakerian lecture for 1807, Davy (1778–1829) describes his isolation of the elements, potassium and sodium, by means of electrolysis. These and similar achievements led up to the electrochemical theory of Berzelius which dominated the entire field of chemistry for more than a generation. During these two decades following Volta, nothing in the shape of a galvanometer was available except a tube containing some electrolyte, which must have rather effectually quenched the current which it was intended to measure.

* Cavendish, *Phil. Trans.*, 1784, p. 119.

The Discovery of Electromagnetism.—One can imagine, therefore, with what delight men realized that, in the simple announcement which came from Copenhagen on the 21st of July, 1820, there was put into their hands not only a totally new relation between two hitherto separate fields of physics, but also a simple and sensitive means of measuring electric currents. But the story of Oersted's discovery of electromagnetism is too well known to need rehearsal before this audience. The achievement has more than once been described as an accident; but I find nothing to substantiate this view. Oersted's works have been recently published in three superb quarto volumes. In one of these papers (Oersted, *Scientific Writings*, Vol. I, p. 61) it is made clear that some ten years before his great discovery he had anticipated a connection between "electric, galvanic, magnetic and chemical effects."

Every student of physics should, early in his career, feel out the magnetic field about a straight wire conveying a current and see for himself the elevation and depression, the deflection to right and left as one carries a small magnet about a horizontal wire conveying the current.

Our deepest interest in the Oersted phenomena lies perhaps in the eagerness with which Ampere seized upon it and promptly wrested from nature not only the discovery that one electric current exerts a force upon another, but also the law which tells us how this action varies with current strength, with distance, and with length of element.

The four fundamental experiments from which Ampere drew these brilliant results were more familiar to an earlier generation than they are to the present. It is from these experiments and one assumption that he derived the idea of a magnetic shell and the simple differential expression from which we obtain at once, by the stroke of a pen, as it were, the laboratory equations for all that class of instruments to which the galvanometer, the current balance, the voltmeter and ammeter belong. It would seem, therefore, highly desirable that they should be early brought to the notice of any serious student of physics. The four experiments are as follows:

(i) A wire doubled back on itself produces no effect on neighboring currents, thus showing that equal currents in opposite senses neutralize one another.

(ii) A straight conductor proves to be equivalent to one which is bent so as to be filled with sinuosities and yet remains near the straight conductor. This shows that an electric current is a vector quantity and can be resolved just as displacements and velocities are resolved.

(iii) A current flowing in the arc of a circle, in a wire which is easily movable about an axis through the center of the circle and perpendicular to the plane of the circle is not affected by any closed circuit placed nearby, showing that the action on each element of the circuit is perpendicular to the length of that element.

(iv) A current is passed in series through three coils which are geometrically similar—coils such as could be obtained by winding them all on one and the same cone, but at different portions of the cone. If now the middle sized coil be made one arm of Ampere's astatic balance, it is found to be always in equilibrium under the action of the other two coils so long as the distance apart of the coils bears the same ratio as their other dimensions.

From these four experimental facts together with the very natural and reasonable assumption that the force between any two elements of the circuit is in the line joining them, Ampere reaches the brilliant conclusion that the magnetic field-strength produced at any distance r by a straight element of current, i, is

$$\overline{dH} = \frac{i\, ds \sin\theta}{r^2} = \frac{i[\overline{r}\ \overline{ds}]}{r^3},$$

where θ is the angle between the directions of r and ds. From this expression the experimental results obtained two years previously by Biot and Savart flow naturally.

The great paper in which Ampere describes these achievements has recently been reprinted by Hermann of Paris and

is easily available; but the best account for modern readers is undoubtedly the brief chapter of fifteen pages which Maxwell, in his *Treatise,* devotes to this discovery. The importance of Ampere's idea of the magnetic shell and the simple relation of equality between the current strength and the magnetic moment of unit area of the shell is not likely to be overestimated by the teacher of physics. No student, indeed, should be allowed to pass this stage of his work without a full realization that this picture of the magnetic shell at once put an end to the belief in two magnetic fluids, so common previously to the year 1826, when the "Theorie Mathematique des Phenomenes Electrodynamique" was first published.

The most exquisite establishment of the existence of the Amperian currents is perhaps that which has recently come out of the very refined and clever experiments by Professor and Mrs. Barnett in which they succeed in magnetizing a circular cylinder of metal by rotating it about the axis of the cylinder—experiments which also indicate that the ultimate magnetic elements—whatever their nature—possess angular momentum.

The story of Ampere's life is pathetic from start to finish. It is told briefly and entertainingly by Henry James in his essay on "The Two Amperes;" but the original account of the brilliant father and son is to be found in their "Correspondence et Souvenirs" collected by Madame Chevreux and covering the years from 1805 to 1864. (Paris, J. Hetzel et Cie.) The ups and downs of this emotional soul may be read in the inscription which he himself suggested for his tomb: *Tandem felix.* "Happy at last."

If we pass hastily by the electric motor completed and put into operation by Faraday on Christmas day 1821, and the "stellate wheel" of Barlow perfected in 1823, and the remarkable discovery of thermo-electric currents which Seebeck reported to the Berlin Academy in 1822, it is not because these are of minor importance, but merely because time is short.

The Problem of Metallic Conduction.—Our next serious indebtedness is perhaps to George S. Ohm (1787–1854). Here again we find an investigator standing upon the shoulders of his predecessors. For as early as 1821, Davy * had

* Sir Humphry Davy, *Phil. Trans.*, 1821, p. 433.

established the experimental fact that the conductance of a uniform wire varies directly as its cross-sectional area and inversely as its length. Just how he did this without the aid of either ammeter or voltmeter is worthy of a moment's notice. The wire which was being studied was used as a shunt to an electrolytic cell filled with water. The length of wire was varied until, in each case, the decomposition of the water just ceased. Any two wires which, with a given battery, would just bring about this effect were considered to have equivalent resistances.

The year following these experiments of Davy appeared the great creation of Fourier (1768–1830), his "Théorie analytique de la Chaleur," the fundamental contribution of which was his definition of *thermal conductivity* as the ratio of "heat flow" to "temperate gradient."

$$k = \frac{\text{Heat Flux}}{\text{Temp. grad.}} = \frac{\left(\frac{H}{t}\right)\Big/a}{T/l} = \frac{Hl}{atT}$$

$$\frac{1}{\rho} = \frac{\text{Elec. flux}}{\text{poten. grad.}} = \frac{\left(\frac{Q}{t}\right)\Big/a}{E/l} = \frac{Ql}{atE}$$

or,

$$\frac{1}{\rho} = \frac{u}{e}$$

or,

$$\frac{a}{\rho l} = \frac{Q/t}{E} = \frac{i}{E} = \frac{1}{R}$$

where H = quantity of heat,
T = temperature,
t = time,
l = length of conductor,
a = cross-section of conductor,
E = E.M.F.,
e = electric field strength,
u = current density,
ρ = resistivity,
R = resistance.

The achievement for which Ohm will always be remembered is that he saw with clear vision and showed by experiment that one has only to substitute "electric flow" for "heat flow" and "potential gradient" for "temperature gradient" in order to describe with accuracy the flow of electric currents.

Underneath both these laws is the tacit assumption that the flux is strictly proportional to the driving force, whether it be thermomotive or electromotive. This assumption did not receive universal acceptance at the time. It was not indeed until the invention of a constant source of E.M.F., first realized in the Daniell cell in 1836, that Ohm's statement could be considered as well verified. In 1847, Kirchhoff (*Pogg. Ann.*, 72) succeeded in generalizing the law of conduction in his two well known statements, one describing what happens in any mesh, the other what happens at a junction point. And it was not until 1865 that Maxwell generalized the statement once again so as to include the behavior of varying currents, and the effect of a neighboring current. As late as the '70's Maxwell was so skeptical of Ohm's simple description that one of the first serious investigations undertaken in the then new Cavendish Laboratory was that of George Chrystal upon the validity of Ohm's law. The result of the investigation was the establishment of the law, over a wide range of currents, as absolutely accurate within the limits of experimental error. The beginning student will at once recognize such differences between heat and electricity that the instructor who follows the historical order of presentation will run no risk of minimizing either the originality of Ohm or the importance of his law.

The enunciation of this simple expression which defines resistivity as the ratio of the electric field-strength to the current density, gave rise at once to this question: Upon what properties of a substance does its resistivity depend? After the lapse of an even century this question remains, except in the case of gases, one of the outstanding puzzles of modern physics. The solution which H.A. Lorentz gave some years ago was suggestive; but that is all that can be said for it. The recent paper of Sommerfeld * on metallic conduction is one

* Sommerfeld, *Zeitschrift fur Physik*, 47, 1–60, 1928.

whose mathematical mazes I make no pretence of following. At the present moment it is as highly praised by an eminent physicist of Oxford University (H. F. Biggs, *Nature*, 121, 505, 1928) as it is severely criticised by an equally eminent physicist (Professor E. H. Hall) at Harvard University. It is, therefore, perhaps fair to say that the problem started by Ohm in 1828 is still awaiting more complete knowledge of the structure of metals. At the time when his "*Galvanische Kette*" was published in 1827, Ohm was teaching mathematics in a secondary school in Cologne; at the time of his death in 1854 he occupied the chair of experimental physics in the University of Munich, the position now held by W. Wien.

The Second Law of Electromagnetism.—It was on the 24th of November, 1831, that Faraday described to the Royal Society of London what is perhaps the greatest single discovery ever made in electrical science. Paragraph 27 of this paper has for a subheading "The Evolution of Electricity from Magnetism," a title indicating at once that Faraday's new phenomenon is the converse of the Oersted effect and foreshadowing its later inference * from the results of Oersted alone. The story of Faraday's long search for induced currents and his final discovery of them is already so familiar to you that no repetition of it is here needed.

New electromagnetic phenomena at once unfolded themselves to Faraday with amazing rapidity. The questions which he put to Nature were so clear and definite that she seldom denied him an answer. He made the original discovery with what is practically a modern iron-cored transformer; within a few weeks he had a D. C. generator in full operation; within a few months, electrolysis by induced currents and the identity of induced currents with those of the voltaic cell and the Leyden jar discharge were established. It was fourteen years, however, before F. E. Neumann (1798–1895) succeeded (1845) in discovering the proper potential function and in formulating Faraday's main result in the exquisitely simple terms in which we all now think of it, namely,

* See Richardson's "Electron Theory of Matter," pp. 102–109 (1914) or Larmor's "Ether and Matter."

the electromotive force as the time-rate of variation of the magnetic flux.

$$\text{e.m.f.} = -\frac{dN}{dt}.$$

And it was still another two years before Helmholtz established electromagnetic induction upon a mechanical basis and derived Neumann's expression by a simple application of the principle of the conservation of energy. No student of physics, whether teacher or taught, can afford not to read this little brochure of Helmholtz, "Die Erhaltung der Kraft" (1847), which was refused publication in *Poggendorff's Annalen* and nevertheless became a corner stone in the structure called modern physics. His energy equation includes only three terms and his argument is simple. Those who prefer an English dress will find the paper translated in Taylor's "Scientific Memoirs," Feb. 1853. Just how it comes about that when a bit of copper wire is moved across a magnetic field there is generated in it an e.m.f. is, so far as I am aware, quite as much of a mystery today as it was when Faraday first observed the effect. We now say that at any one point in the metal the electric field generated is $e = (1/c)Hv$ where e is the vector product of H and v; but this is a mere variant of Neuman's expression; and the mystery remains.

Nowhere in his full half-century of scientific work are the two distinguishing characteristics of Faraday's mind better displayed than in this paper "On the Induction of Electric Currents." I refer to his unbounded respect for the facts and his powerful imagination, which, as one of his biographers says, sometimes rose to divination. In Faraday's notebook, under date of 19 March, 1848, is found the following entry:

"Nothing is too wonderful to be true if it be consistent with the laws of nature; and in such things as these experiments is the best test of consistency."—Bence Jones, "Life of Faraday," Vol. 2, p. 253.

There is, of course, no such thing as nationality in science; nevertheless American students will, I believe, read with especial interest the still earlier discovery of induced currents

made by Joseph Henry but not published by him until nine months after Faraday's Royal Society paper of November, 1831.

Another of the priceless possessions which we students of physics have inherited from Faraday is his mode of tracing electric and magnetic actions through the medium and his representation of these vector fields by means of lines of force. To grasp our indebtedness one has only to imagine himself teaching the subject without being allowed to mention lines of electric or magnetic force.

Electric science becomes quantitative.—In conclusion, let us pay our respects to the men who first taught us that modern physics is to a large extent an answer to the question *How much?;* the men who for the first time reduced electric and magnetic measurements to those of ordinary mechanics. And here, without forgetting the quantitative aspect of much of the work of Coulomb and Cavendish in the 18th century or that of Davy and Faraday in the early 19th century, we must, by general consent, I believe, consider C. F. Gauss (1777–1855) the pioneer; for it was this eminent astronomer and mathematician who in 1833 cut his way through a forest of hazy ideas and made a clear path to the measurement of a magnetic field in absolute units. The field intensity once expressed in terms of fundamental units led immediately to the expression of current, electromotive force, and resistance in terms of length, mass and time.

The first reduction of resistance to mechanical units was that made by Gustav Kirchhoff* (1824–1887) and described by him in *Poggendorff's Annalen* for the year 1849. The young Kirchhoff was at this time only twenty-five years of age, having been born in the same year with Lord Kelvin. He was the same Kirchhoff who, ten years later, was to lay the foundation of the science of spectroscopy. In this paper, however, he made no effort to establish a system of absolute units, but contented himself with showing that one might either assume an arbitrary piece of copper wire as having a unit resistance and then evaluate the constant of Neumann or one might assume Neumann's constant as unity and then

* Kirchhoff, *Pogg. Ann.*, 76, 412–426 (1849).

evaluate the resistance of the wire. It is this latter alternative, of course, which we employ today when using Kirchhoff's method for measuring resistance. The principle which Kirchhoff employs is one that is now so widely used in electrical laboratories that it need be merely indicated.

The first step in his method is to take two coils of such a shape that their coefficient of mutual inductance can be readily computed, and place them in separate circuits, one near the other. When the steady current, i, in the first coil is reversed, the quantity of electricity, Mi/R, induced in the second circuit is measured by a galvanometer used ballistically. The next step is to put a steady current through the circuit of the second coil by using the e.m.f. which exists between two points on the first circuit, the one conveying the current i. Thus one obtains two equations which yield him the resistance between these two points in absolute measure, namely,

$$\frac{Mi}{R} = a \sin \theta/2, \quad \frac{ir}{R} = b \tan \phi, \quad \therefore r = M\left(\frac{b}{a}\right)\left(\frac{\tan \phi}{\sin \theta/2}\right),$$

where each quantity in the right-hand member is easily observed or computed. This is, of course, a far cry from our modern highly perfected system of electrical units; it is nevertheless one of the foundation stones upon which this system is built. No method involving the ratio of two galvanometer deflections could possibly be used today for the determination of the ohm. Therefore a highly ingenious and clever modification of Kirchhoff's method, using only the null point of the galvanometer, has been devised by Dr. Wenner and is on the program for the immediate future at the Bureau of Standards.

Looking back over the first half of the nineteenth century, we find on the debit side of the ledger the following items which so far from being out-of-date are in daily use:

(i) The Voltaic cell; of which it is estimated that, during the past year, no less than 500 millions were manufactured in the United States alone.

(ii) The first law of electromagnetism; $W = 4\pi i$, discovered by Oersted, perfected by Ampere, Biot and Savart, the basis upon which a large portion of our electrical measuring apparatus is designed.

(iii) The second law of electromagnetism; discovered by Faraday, perfected by Neumann and Helmholtz, the basis upon which most of our electromagnetic machinery is designed.

(iv) The creation of the science of electrodynamics and the first step in the explanation of magnetism by Ampere.

(v) The establishment of Ohm's law on a firm experimental basis.

(vi) The identity of electrifications, derived from all the various sources, chemical, thermal, frictional, magnetic, and dynamical, placed beyond dispute.

(vii) A host of minor phenomena—if one dare call any phenomenon a minor one—such as the polarized cell of Ritter; the thermoelectric current of Seebeck, and its converse discovered by Peltier; the mechanical energy of a charged Leyden jar, $1/2\ CV^2$, first established by Joule (Roy. Soc., 1840) and Helmholtz ("Erhaltung der Krafte," 1847).

Besides these a long list of other phenomena which have not even been mentioned, such, for example, as the Page effect discovered by an examiner in the American Patent Office.

This first half century represents the assault upon the one great problem of electricity and magnetism; tomorrow we shall consider the victory obtained in the second half century.

PART II

In his remarkable book called "Constructive Citizenship," Principal Jacks has pointed out in a forcible manner the marked difference between thinking out a plan for the present and thinking forward to discover how this plan will work in the future. The first of these processes he calls *space-thinking;* the latter, *time-thinking.* The first is one of the easiest things in the world; the latter is one of the most difficult.

Yesterday, we were thinking backwards in time, trying to appraise the important phenomena and worthwhile methods discovered in the first half of the nineteenth century. This was done in the hope of deriving from it some training in looking forward.

Thinking seriously about anything is proverbially difficult; thinking aloud is positively hazardous. Professor Gilbert N. Lewis, in his brilliant volume, "The Anatomy of Science," says that "every decision of life is a gamble." This is a statement which must evoke the warm sympathy of any man who has ever tried to push aside, ever so little, the veil which hides the future. What then shall be said of the man who takes his stand at the year 1850 and tries to think forward in time to the year 1900? The human accomplishments of that half century in physics would stagger the most powerful imagination.

Your attention is invited to the achievements of those fifty years in the hope of an increased skill in time-thinking; in the hope of a keener realization that it is the unexpected that happens, and in the hope of a greater confidence in the doctrine of Faraday that "nothing is too wonderful to be true;" and yet in the hope that we may not acquire such high respect for the past as to become fundamentalists in science.

Electrical Units.—The possibility of measuring both magnetic and electrical quantities in terms of mechanical units had already before 1850, been firmly established by Gauss and Kirchhoff. In practice, however, a certain arbitrary unit of resistance (about 8 meters of copper wire some 2/3 mm. in diameter) had been chosen and widely circulated by Moritz Jacobi (1801–1874), brother of the mathematician, Carl Jacobi. The stage was all set, therefore, for Wilhelm Weber to determine the value of the Jacobi unit in absolute measure. This he did in 1851. *Pogg. Ann.*, 82, 337–369, (1851). The literature of the fifties is full of references to "Weber's absolute units." The absolute unit of current was shortly afterwards named after Weber. I find in my undergraduate laboratory notes at Princeton, made in the early eighties, that all measured currents are recorded in *webers*. Indeed, it was only on the proposal of Helmholtz, made to the International Electrical Congress at Paris in 1881, that the name of Weber was replaced by that of Ampere.

From this point on, the system of absolute electrical units must be considered an accomplished fact. The great problems, which remained and which have been solved largely by the efforts of the Brit. Assoc. Adv. Sci. during the interval between the appointment of the first committee in 1862 and

its final report in 1912, have been the choice of the three fundamental units, the choice of defining equations for the various electrical quantities, the experimental evaluation of certain electrical standards, and the adoption of appropriate names for the electrical and mechanical units. The whole story of the work of this famous B. A. Committee is admirably told in a summary of their reports recently published by the Cambridge University Press.*

The accuracy now possible in measuring these electrical quantities in mechanical units is so high that, as some of you perhaps know, resolutions are to be presented to the International Committee on Weights and Measures at its next meeting (1929) which will recommend the abandonment of the international ohm as represented by the mercury column and also the international amperes as represented by a silver deposit. Instead of these, will be recommended the direct determination of electrical quantities in terms of mechanical units; the volt, for example, from the Lorenz apparatus; the ampere, from Joule's current-weigher; and so on.

In a class of one hundred students graduating as electrical engineers, each perfectly familiar with the uses of graded instruments which read directly in amperes, volts, watts and henries, few, I venture to think, of these men have any adequate idea of their indebtedness to Kelvin, Maxwell, Fleeming Jenkin and Latimer Clark who determined the early standards of resistance and electromotive force; or to the Paris Congresses of 1881 and 1889 which gave us the volt, the ampere, the ohm, the joule, the watt and a whole series of brain-saving definitions for alternating currents; or to the Chicago Congress of 1893 which defined and named the henry; or to the later congresses which gave us a coherent system of magnetic units including the gauss (Ipswich: 1895) and the maxwell (Paris: 1900).

If any one thinks that the universal adoption of such a unified system comes about automatically and by mere passive acceptance, he is very slightly acquainted with the inertia of

* An extended account of the origin and development of electrical units will be found in two lectures entitled "The History of Electrical Units," delivered by A. E. Kennelly at the Electrical Engineering Session of the Summer School for Engineering Teachers, to be published in the November, 1928, number of JOURNAL OF ENGINEERING EDUCATION.

human nature and he must be a perfect stranger to national prejudice. The men who accomplished these things belonged to the type which knows how to "scorn delights and live laborious days." If one really desires to learn our obligations to the pioneers who perfected this nicely adjusted quantitative system of units, he has only to stand (as I did, a few weeks ago) at the great Crawford Avenue Station in Chicago, beside a quiet gentleman—known as the load-dispatcher—who, seated in front of a table to which there are attached a few switches, a few graduated dials and a few small lamps, has at the control of his finger tips the distribution of 177,000 horsepower.

No teacher of physics can afford to look upon this series of events which has resulted in our exquisite system of aptly related electrical units as a panorama, or a picture framed and hung on the wall, forever belonging to the past. On the contrary it is a moving picture; at each instant there is a changing group of men; they are on the top of the wave, carried forward by the same irresistible drive that urges you or me toward any present goal; never reaching the end except to find there a new goal farther on; in this case a higher degree of accuracy and greater convenience.

The Open Circuit and Electric Waves.—We pass now to a field of electrical discovery which for a full half century was quietly cultivated in the physical laboratory and which has only recently become a matter of surprising social and commercial importance. In the first half of the century we are studying, three men had a fairly clear grasp of the fact that the only electrical phenomena which we know anything about are *mechanical* phenomena. These men were Ampere, Gauss, and Helmholtz. Ampere balanced torques; Gauss measured magnetic moments; Helmholtz used the energy equation. But it is not until the second half of this century that anyone thoroughly grasped the idea that an electric circuit is essentially a dynamical system, and employed this idea to make important predictions.

As early as 1851, Kelvin (*Phil. Mag.*, Dec. 1851) had given a mechanical, though not a purely mechanical, definition of electromotive force, which runs as follows: The e.m.f. between any two points on a conductor is numerically equal to the *rate* at which work is done between these two points when

unit current is passing through the conductor. And only two years later, we find Lord Kelvin * publishing in the *Philosophical Magazine* under the title "Transient Electric Currents," a complete dynamical account of the behavior of an open circuit. Kelvin describes the exact conditions under which an open circuit discharge must become oscillatory and shows himself to be a thorough master of those mechanical analogues which our colleague, Professor W. S. Franklin has stressed so splendidly in his teaching. An interval of four years elapsed between Kelvin's prediction of the oscillatory discharge and Feddersen's † clever experimental verification of it. I may remark parenthetically that the original rotating-mirror-device by which Feddersen demonstrated this fact forms one of the many highly instructive exhibits of the Deutsches Museum at Munich. And since I am digressing I may add that no teacher of physics, who once finds himself in Europe, should ever think of returning home without first visiting this marvellous and unique collection at Munich, a duty and a pleasure for which three full days is an irreducible time-allowance.

In the same year with the Feddersen experiment, Kirchhoff ‡ had described the propagation of waves over wires by means of his justly celebrated *Telegraphic Equation*. It was also about this same time, 1856, that Weber § and R. Kohlrausch first determined the ratio of the electromagnetic to the electrostatic unit of quantity and found it to be practically the same number as that which represents the speed of light.

The properties of various media, including the one which we call a vacuum, had long before been carefully observed by Cavendish and Faraday. All the problems, indeed, whose solutions were necessary for the design and operation of the Atlantic cable were being solved. In a series of five separate papers which appeared in the *Philosophical Magazine* between the years 1861 and 1862, Maxwell ‖ had described a

* Kelvin, *Phil. Mag.*, June, 1853.

† Feddersen, *Pogg. Ann.*, 103, 69 (1857).

‡ G. Kirchhoff "The Motion of Electricity in Wires," *Pogg. Ann.*, 100, 193, (1857); *Ges. Abh.*, p. 131.

§ Weber, *Werke*, Bd. 3, p. 609.

‖ Maxwell, *Phil. Mag.*, 21, 161, 281, 338 (1861); 23, 12, 85 (1862).

mechanical model of the electromagnetic medium and had thrown into a set of consistent equations all the most important results of Oersted, Ampere and Faraday. In fact the stage was all set for the reading of Maxwell's momentous paper on the Electromagnetic Field before the Royal Society of London on the 8th of December, 1864. The brilliant stroke by which this Scotch genius, at the age of thirty-three, reduced the whole domain of optics to a mere subdivision of electromagnetism is perhaps without a parallel in the entire history of physics.

It is true that the main results of this Royal Society paper are set forth in Chapters VIII and XX of Maxwell's great "Treatise." Nevertheless every teacher of physics will be sure to get a thrill, as well as an enlarged and unitary view of the entire electric field, by following the original memoir. The argument is based upon eight different relations and one assumption covering the principal facts of the science; these are described by twenty different equations involving twenty variable quantities; but the reading is not formidable and the reward is ample.

The assumption which Maxwell makes is that displacement currents produce a magnetic field, a supposition which was not justified by experiment until twelve year later when, in Helmholtz's laboratory, Rowland actually measured the magnetic field produced by an electrostatic charge when put into mechanical motion—a piece of manipulation so difficult that most of the experimenters who attempted to repeat it within the next twenty years failed to obtain the effect.

The essence of the entire discussion is resumed in the four vector expressions which are now known as Maxwell's equations and which are doubtless more familiar to many of you than to me. A. G. Webster used to put the matter in words of one syllable as follows: Two relations exist between magnetic and electric inductions and their forces, namely: *The curl of either force is equal to the time derivative of the other induction,* and, *Either induction is a linear vector function of its own force. Phys. Rev.,* 3, 237 (1895). From these equations and from the fact that the divergence of each force is zero, Maxwell deduces the reflection, refraction and polar-

ization of electric waves. Here, indeed, is the charter of the American Institute of Radio Engineers, published to the world twenty-four years before any man had learned how to produce electric waves in the laboratory. However, since physics is an experimental science, it is perhaps only fair to say that these equations of Maxwell's were never thoroughly established until the year 1888 when their competency and sufficiency was so amply demonstrated by the clever experiments and penetrating mind of Hertz at Karlsruhe. In this connection the teacher of physics has always to remember that the two laws of electromagnetism, as ordinarily used, are integral in form, and deal only with conduction currents. The teacher must also be pardoned for putting the emphasis upon those men whose labors have borne fruit. Elihu Thomson and D. E. Hughes doubtless anticipated Hertz in the production of electric waves; but no important results followed from their experiments.

Maxwell's equations have been derived in various ways other than that employed by Maxwell himself, as, for example, that of Sir J. J. Thomson, *Phil. Mag.*, 31, 149 (1891); but for us teachers of physics, I am inclined to think there is no presentation which is at once so illuminating and so clear as that given by Hertz, *Wied. Ann.*, 40, 577 (1890), some two years after his discovery of electric waves, in that remarkable paper entitled "The Fundamental Equations of Electromagnetism." There are two parts to this paper. In the first, Hertz throws the equations into a beautifully symmetrical form; in the second part, he shows how one can derive from them, in succession, each of the separate sciences: electrostatics, magnetism, electromagnetism and optics. This paper is, indeed, the counterpart and complement of Maxwell's Royal Society paper of 1864. The same symmetrical treatment will be found in Heaviside's "Electrical Papers" (Vol. 1, p. 429 and Vol. 2, p. 375) in a style which is much more diffuse, but which has the advantage, for most students and many teachers, of being in English.

In spite of any symmetrical form which may be given to these equations, it is only fair to the student to point out the three inherent differences between the electrical and the magnetic situation, which are as follows:

(i) No substance exhibits magnetic conductivity;

(ii) True magnetism is unknown; i.e., surface integral of induction is always zero.

(iii) Magnetic permeability is, in some substances, less than unity; while the dielectric constant is always greater than unity.

So far as concerns radio-communication—the most fashionable, perhaps, of all the sciences at the present moment—it is clear, I think, that our indebtedness is mainly to Faraday, Maxwell and Hertz for what we know about the production and the properties of these waves.

The Edison Effect.—But the detection of these radiations is only second in importance to their production; and therefore we must not forget our obligation to the man who, at the electrical exhibition held at Philadelphia in the autumn of 1884, exhibited to some of his friends an incandescent lamp, into the bulb of which was sealed a second electrode. The diminutive current which Mr. Edison obtained by connecting this electrode with the positive side of the filament was then, and was for some years after, merely an electrical novelty, a scientific curio, to nearly every one except Sir William Preece who went back to England and immediately began the study of it. This is the one phenomenon which is met with on a large scale in the modern kenetron.

The vast importance of this *Edison effect* was, however, only realized seven years after the end of the century when a young Yale graduate sealed a *third* electrode into the incandescent lamp and taught us how to control the thermionic current of the Edison tube by slightly varying the potential of this third electrode, the well known "grid" of de Forest.

And since I am already outside the limits of our chosen century, I cannot resist mentioning an achievement which, in a certain sense (that is, so far as the elements of the subject are concerned), completes the series; but which is, by no means, the last important discovery in radio-communication. I refer to the invention of the regenerative circuit, 1913; whether first devised by de Forest or by Armstrong or by Meissner, I shall not attempt to say. Recent advances in wireless communication, such as the discovery of the Kennelly-

Heaviside layer, the introduction of short waves, the directivity of receivers and the so-called echos of messages passing entirely around the world, command our admiration; but we teachers of physics cannot afford to lose perspective by forgetting the pioneers of the nineteenth century who made all this possible.

The Moving Coil Galvanometer.—Among the many clever devices connected with the Atlantic cable, there is one for which I think every teacher of physics feels especially grateful to the inventor. I refer to the siphon-recorder which Lord Kelvin patented in 1867 and which is the parent of all other forms of the moving coil galvanometer, including the D'Arsonval pattern which during the eighties drove nearly every other current detecting device out of the teaching laboratory. Indeed, it has now come to the point where any industrial establishment, any motor boat, any air-plane, or any second-hand Ford car without a moving coil ammeter would be a curiosity. The perfection of design which that modest scholar, Mr. Edward Weston, gave this instrument during the late eighties and the early nineties is attested by the fact that his ammeters and voltmeters of that date are still rendering excellent service.

Electromagnetic Machinery.—It is well known that the electric whirl and other electrostatic devices for producing rotation are so inefficient that they have only a purely scientific interest. The tiny electric motor devised by Faraday immediately after the discovery of the Oersted effect has also remained a scientific curiosity. The boat which M. Jacobi drove along the Neva at St. Petersburg in the following decade was furnished with an electric motor of ¾ horsepower; but electrically driven motor-boats did not become the fashion in the thirties.

(i) The first important advance in the perfection of the modern motor—the step which put the motor beyond the toy stage—we owe to a young sergeant in the Garibaldian army of 1859, Antonio Pacinotti (1841–1912), shortly afterwards Professor of Physics in the University of Pisa. In 1860, Pacinotti constructed a small motor which involved two radically important ideas. The first of these features is the ring-wind-

ing, subsequently and independently invented by the Belgian engineer, Gramme; the other is the iron-toothed armature which has the double advantage of reducing the air-gap and of furnishing protection of the active wires against mechanical drag. Pacinotti first described his machine in the *Nuovo Cimento* for March of 1865; and enunciated at this time the general principle that the motor is nothing but the generator reversed in function. This paper may be found translated into English by S. P. Thompson in a memorial volume published at Bergamo in 1912, the year of Pacinotti's death.

(ii) The next important contribution is, I think, the discovery which came, two years later, in 1867 when Dr. Werner Siemens and Sir Charles Wheatstone independently and simultaneously hit upon the idea that the field of a dynamo may be excited from the residual magnetism retained by the soft iron core of its electromagnet.

(iii) The third advance in motor development appears under the date of 1875 when H. A. Rowland published in the *Philosophical Magazine* (p. 257) that one of his papers on magnetism in which he explicitly sets forth the doctrine of the magnetic circuit, a paper whose merits so impressed Clerk Maxwell that he shortly afterwards recommended Rowland for the newly created professorship of physics at Johns Hopkins University. It was this idea of Rowland's, ably supported by R. H. M. Bosanquet and J. Hopkinson in England, that dictated the short legs, gentle lines, and small air gap for the modern generator. Such helpful names as *magnetomotive force* and *reluctance* had not yet been adopted; but all the ideas were there; and Ohm's law was fully realized as very approximately describing the magnetic circuit as early as 1875.

In the year following, Gramme exhibited two or three of his generators at the Centennial Exposition in Philadelphia. From this time on, improvements came by the dozen. In 1884, Lord Rayleigh ventured the prediction, in his Montreal address before the British Association, that the future of electrical power developments lay along the line of alternating currents. In 1893, the induction motors exhibited at the World's Fair in Chicago had an efficiency of something like

30 percent. Polyphase transmission was just coming to the front and at the International Electrical Congress of '93, it was much discussed by such active minds as those of the late Louis Bell and the late Silvanus P. Thompson.

It will perhaps not be far from the truth, therefore, if we say that during the second half of the Nineteenth Century a small group of pioneers perfected and turned over to us almost as we have them today, the motor, the generator, and the transformer. No one will imagine, I trust, that the list of men mentioned is by any means complete; nevertheless the names of Pacinotti, Siemens and Wheatstone, Rowland and Bosanquet are likely always to be associated with the evolution of electromagnetic machinery.

The Telephone.—If one were to decide by popular referendum what electrical invention of the 19th Century places us under the greatest obligation, the telephone would, I suspect, obtain a plurality of all the votes cast. Here again the honors are difficult to allocate. But informed opinion will, I believe, pass over the anticipations by Philipp Reis (1834–1874) and stop first at the names of Alexander Graham Bell (1847–1922) and Elisha Gray (1835–1901). Each of these two men realized that intermittent currents are incompetent to reproduce human speech. Each of them proceeded to construct in 1876 an instrument depending upon the fluctuations of a continuous current brought about by the rapid fluctuations of pressure in the atmosphere caused by the human voice.

The story of Elisha Gray, filing his caveat only two hours after the application for patent by Graham Bell, is one of the best known of American stories. Joseph Henry and Lord Kelvin, within a few months after the invention of the telephone, pronounced it the most interesting exhibit in the Centennial Exposition. A few months later, Maxwell chose "The Telephone" as the subject of his Rede lecture. Within a year or two, several microphonic transmitters had been devised, thanks to Hughes, Berliner, Blake and others. By 1878, exchanges were established in our larger cities. The eagerness, indeed, with which the American people seized upon this device and put it into service is without precedent.

The Hall Effect.—The year 1879 is memorable in the his-

tory of electrical science as the date when a certain young man, still living in this city and still a young man in spite of anything the calendar may say, announced his discovery that the presence of a magnetic field profoundly modifies the distribution of equipotential surfaces in a conductor conveying an electric current. This well-known *Hall Effect* has been one of the outstanding puzzles of physics for well nigh half a century. The magnetic field in some way changes the conductivity of the metal; and this phenomenon, therefore, falls into the same general class with the problem of metallic conduction which, as we saw yesterday, has remained from the time of Ohm an unsolved problem, unless we accept the recondite explanation, given in terms of statistical mechanics, a few months ago by Sommerfeld. What Professor Hall had proved was that when a current flows through a metallic conductor placed in a magnetic field, the mere presence of this constant field establishes an e.m.f. which, at any point, is parallel to the mechanical force acting on the conductor at that point. So far as I am aware no one has yet explained why a winding on the armature of a motor moves at right angles to both current and field; nor has anyone yet explained why the e.m.f. of Hall appears at right angles to both current and field. This discovery of Professor Hall's was made in the first physical laboratory at Johns Hopkins University, consisting of the kitchen and two or three other back-rooms in what was formerly a private residence at the corner of Howard and Little Ross Streets in Baltimore. No other disclosure in this half centry has perhaps given rise to so many serious efforts to find an explanation. Professor L. L. Campbell, in his admirable volume dealing with the Hall and allied phenomena, lists no less than 618 papers up to the year 1923.

At first glance one might consider the Hall effect more of a liability than an asset; but the case is quite otherwise; for aside from the fact that nothing is more uninteresting than a solved problem, these many efforts have not been barren; within ten years after the first announcement of the Hall effect came three analogous effects; *first*, that of Nernst in which he discovered that, when a current of *heat* is flowing through a plate of bismuth, an e.m.f. is set up between the edges of the plate as soon as a magnetic field is put on.

A *second* effect was that discovered simultaneously and independently by Righi and Leduc, in 1887, that when a heat current is flowing along a plate, a difference of *temperature* between the edges is set by putting on the magnetic field.

And *thirdly* there is the Ettinghausen effect announced in 1887, namely, that when an electric current flows along a metal plate, the introduction of a magnetic field suffices to establish a difference of temperature between the edges of the plate.

Besides these four beautifully symmetrical effects, there is the Corbino effect of our present century (1912) which, however, may be only a special case of the Hall effect in radial currents. In any event, here are four challenges which we inherit from the nineteenth century; they have been accepted without hesitation. The problem is difficult beyond compare. The laws of the phenomena are full of anomalies, so-called. The final reply to the challenge must be nothing less than a complete theory of electric and thermal conduction; of which at present only a beginning has been made in the case of gases.

The Discrete Nature of Electricity.—In these days, when all physical views are expressed in terms of electrons, one must either have a well trained imagination or must have many years to his credit in order to understand the hesitation which the physicists of the Victorian period exhibited in accepting the idea that electricity is discrete in nature.

As far back as 1833, Faraday * expresses himself by saying that "if we adopt the atomic theory or phaseology then the atoms of bodies which are equivalent to each other in their ordinary chemical action have equal quantities of electricity naturally associated with them."

"But I must confess," he adds, "I am jealous of the *atom;* for though it is very easy to talk of atoms, it is very difficult to form a clear idea of their nature, especially when compound bodies are under consideration."

Forty years later, Maxwell,† in discussing the same phenomena of electrolysis says; "But if we go on, and assume

* Faraday, "*Experimental Researches,*" § 869.
† Maxwell, "*Treatise,*" § 259.

that the molecules of the ions within the electrolyte are actually charged with certain definite quantities of electricity, positive and negative, so that the electrolytic current is simply a current of convection, we find that this tempting hypothesis leads us into very difficult ground."

Another ten years and Helmholtz * tells an audience at the Royal Institution in London that "The most startling result of Faraday's Law is perhaps this; if we accept the hypothesis that the elementary substances are composed of atoms, we cannot avoid concluding that electricity also, positive as well as negative, is divided into definite elementary portions which behave like atoms of electricity."

Another ten years, approximately, and G. Johnstone Stoney † has computed the numerical value of this smallest possible electric charge and has proposed for it the name *electron.*

As early as 1879, Crookes had shown how a pencil of cathode rays might be produced and deflected by a magnet; and he firmly maintained the view that these rays consist of negatively charged particles. For sheer lack of time we omit all mention of important results obtained by Hittorf, Goldstein, Schuster, and others.

But it was not until 1894 that Sir J. J. Thomson, *Phil. Mag.*, 38, 358 (1894), took up the serious study of electric discharge in gases. Even at the close of his Princeton Lectures in 1896, he felt warranted in supporting "the view that in the corpuscles in the cathode rays we have matter in a finer state of subdivision than the ordinary atom" and spoke of ordinary elements as "made up of corpuscles and holes, the holes being predominant"; but the beautifully devised quantitative experiments by which Thomson established the existence of the electron, measured its mass and discovered many of its other properties are set forth in three remarkable papers appearing in the *Philosophical Magazine* for the years 1897, 1898 and 1899. This subdivision of the atom, announced to the British Association in 1899, brought with it a host of new conceptions, both chemical and physical; gave us new suggestions concern-

* Helmholtz, *Nature*, (1881).

† G. J. Stoney, *Phil. Mag.*, 38, 418 (1894).

ing the structure of matter, a new approach to the problem of electric and thermal conduction, and what is a priceless possession for any of us students, a unitary view of the whole subject. Let us then consider the electron theory of matter as the last great debt which we owe to the electricians of the nineteenth century. But how dare I take my seat without mentioning that exquisite contribution of Pupin's—the loaded cable—which came right at the end of the century? Or its natural sequel, that beautifully responsive substance, permalloy?

Students of politics know only too well that traditions are necessary to maintain the continuity of a government. If you have any doubt about this, read again the latest Democratic platform and observe how they "believe with Jefferson," "reaffirm with Jackson," "agree with Cleveland" and "pay tribute to Wilson." Science and engineering today occupy the same house; and this building rests upon a foundation which we have inherited from the past. This foundation corresponds to the traditions of politics; it is "the living past" to use F. S. Marvin's phrase or "the past at our doors," as Skeat calls it.

On the other hand, no duty of the teacher is more imperative than to give the student a realizing sense of the incompleteness of the foundation of electrical science, and to put him in touch with as many unsolved problems as possible, and above all to teach him that there is no such thing as finality in science, and that no discussion of any topic in physics is ever complete.

From Volta to J. J. Thomson there is nothing concerning which the last word has been said. Much remains to be done. Let us not forget then that all ledgers have a credit as well as a debit side. What we have inherited from the ages is a measure of the service demanded of us.

REPORT ON TECHNICAL NOMENCLATURE.

Many of the members of the Society for the Promotion of Engineering Education will be interested in the work of the American Engineering Standards Committee in the standardization of scientific and engineering symbols and abbreviations. ENGINEERING EDUCATION for May, 1926, showed on pages 630–631 the plan of organization through which this standardization was to be effected. The sponsors are five American national societies, one of which is the Society for the Promotion of Engineering Education. The general relationship of the Society for the Promotion of Engineering Education to the whole scheme is shown on an organization chart on page 631 of the issue of ENGINEERING EDUCATION for May, 1926.

According to this scheme the field was divided into seven parts, each under a chairman of a subcommittee. A number of tentative reports have been published, and a few final reports. ENGINEERING EDUCATION for June, 1927, pages 919–924 inclusive, shows one of the reports. Pages 758–765 inclusive of the issue for May, 1927, contain brief statements of progress. Other reports have been published in various engineering journals, and it is possible that all of the reports will be coordinated and published before the end of the current year.

One of the subcommittees, that on Mechanics, Structural Engineering and Testing Materials, has collected information from various sources and has compiled it in the following form. The concepts for which symbols are desired are shown on the left of each column and the symbols for these concepts suggested by various authors, societies, and professors are shown in the vertical columns. For instance, column 4 shows the symbols submitted for the various concepts by C. A. Norman, of Ohio State University. The symbols have been

Column
1 Symbols approved by the Society for the Promotion of Engineering Education.
2 Handbook of the Bethlehem Steel Company.
3 Handbook of the Carnegie Steel Company.
4 C. A. Norman, Ohio State Univ.
5 "Textbook of Mechanics" by E. H. Wood.
6 Symbols of the American Institute of Electrical Engineers.
7 "Rational and Applied Mechanics" by C. M. Woodward.
8 "Analytical Mechanics for Engineers" by F. B. Seely and N. E. Ensign.

Column
9 Frye's Civil Engineers' Handbook.
10 Trautwine's Civil Engineers' Pocket Book.
11 "Theoretical Mechanics" by A. Ziwet.
12 Boyd's Strength of Materials.
13 "Strength of Materials" by A. P. Poorman.
14 R. E. Hess, Asst. Sec. Am. Soc. Testing Mat.
15 Amer. Eng. Std's Committee, Sym. for Hydraulics.
16 Amer. Eng. Std's Committee, Sym. for Heat and Thermo.
17 Amer. Eng. Std's Committee, Sym. for Elec. Quantities.
18 R. G. Hudson, Mass. Inst. of Tech. (through H. B. L.)

Column
19 H. B. Luther, Univ. of Cincinnati.
20 E. H. Wood, Cornell University.
21 W. A. Mitchell, U. S. Military Academy.
22 C. M. Spofford, Mass. Inst. of Tech.
23 H. S. Gonnerman.
24 A. F. Puchstein.
25 E. R. Harris, Westinghouse Elec. & Mfg. Co.
26 Amer. Inst. of Steel Construction, Inc.
27 G. M. Braune, Univ. of N. Carolina.
28 P. W. Ott, Ohio State University.

Concepts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Acceleration, angular	α			α	α		α	α			α			α				α	α	α		α	α	α		α	α		
Acceleration, due to gravity	g			g	g	g	g	g	g	g	g			g	g	g		g	g	g	g	g	g	g	g	g	g		g
Acceleration, linear	a			a	a		a	a	a	a	j			a				a	a	a	α	a	a	a	a		a		
Angular distance				θ			θ	θ			θ	θ	θ	θ				θ	θ	θ		θ	θ	θ			θ		
Angular velocity	ω			ω	ω, Ω	ω	ω	ω	ω	ω	ω	ω	ω	ω	ω	ω		ω	ω	ω		ω	ω	ω	ω		ω		
Area	A	A	A	A			A	A			A	A	A	A	A	A		A	A	A	A	A	A	A	A	A	A		A
Area, neutral thru c. of g.		X-X		X-X			X-X	X-X			X-X	X-X	X-X	X-X							X-X	X-X	X-X	X-X	X-X	X-X	X-X		
		Y-Y		Y-Y			Y-Y	Y-Y			Y-Y			Y-Y							Y-Y	Y-Y		Y-Y	Y-Y	Y-Y			
Axis, not thru c. of g.		N-N		N-N			N-N	N-N			N-N			N-N							N-N	N-N		N-N		N-N		
Bending moment	M	M	M	M_b	M		M	M	M	M	M	M	M	M				M	M	M	M	M	M	M	M_b	M	M		
Breadth	b			b			b				b	b	b	b				b	b	b	b	b	b	b	b	b	b		
Center of rotation	O			O			O, C	O			O	O	O	O						O	O	O	O	O			O		
Coefficient of sliding friction	f			f	f		f	μ			μ			μ				f	f	f	μ	f	f	μ	f		μ		μ
Coefficient of rolling friction				μ	c													c	c	f_r				μ_r					
Concentrated load		P		P				P				P	P	P				P	P	P	W	P or F	P	P	P		P		
Constants	C, K			C, K	c			c			c	C	C	C, K				C	C	C	C	C	C	C, K	C		C		
Curvature, radius of				ρ	ρ		ρ	ρ			ρ			ρ				ρ	ρ	ρ		r	ρ	ρ			ρ		
Coefficient of temperature								e				e	ϵ																
Deflection	y	d	D	δ or y			v	y			y	y	y	y				d	d	y	Y	δ	y	y	y	y	y, δ		
Density																		d	d					w					
Depth	d	D	d	d				d			d	d	d	d						d	D	d	d	d		d	d		
Diameter	D			D	D				D		D	D	d	D				θ	θ	d	D	D	D	D	d	d	D, d		D
Distance, angular							θ	θ			θ	θ	θ	θ				s	s	θ		θ		θ			θ		
Distance, linear	s			l	s		s	s			s			s				y	y	s	l	s	S	S	s		s		
Distance, neutral axis to extreme fiber	c	c	n	c			c				c	c	c	c'						c		c	c	c	c	y	c		
Eccentricity of application of load	e			e				e				e	e	e				e	e	e		e	e	e			e		
Efficiency (hydraulic, mechanical, volumetric)	e_h, e_m e_v			e_h, e_m e_v											e or η	$e_h e_m$	η				e_h, e_m, e_v	e		n	n		E_f		$n_h n_m n_v$	ne
Elasticity, modulus of	E	E	E	E			E	E	E	E	E	E	E	E				E	E	E	E	E	E	E	E	E	E		
Elongation				λ									δ					d	Δ	λ	λ	λ		ϵ	λ	e		δ		
Elongation unit																													
Force	F			P	F		F	F	F	F	P	F	P	F				F	F	F	F	F	F	F	F	P	F, P		F	F
Force, moment of	M	M	M	M	M		M	M			M	M	M	M				M	M	M	M	M	M	M	M	M	M		
Frequency (Harmonic motion)				γ				n			n			n					n		n	n	n	n	f	f			
Friction, coef. of sliding	f			f	f		f	μ			μ			μ				f	f	f	μ	f		μ	f		μ		μ
Friction, coef. of rolling				μ	c																								
Gravity, acceler. due to	g			g	g	g	g	g	g	g	g			g				g	g	g	g	g		g			g		
Gyration, radius of	k	r	r	i	k		k	k			r_0	k	k	k				K	ρ	K	r	ρ	k	$R(?)$	$^*k$	r	k		
Head	H			H, h																									
Height	h	h			h		h				h		h	h							h	h	h	h	h	h	h		
Horsepower	hp			N			$H-P$	h.p.	H.P.				hp						hp	hp	HP	H.P.	h.p.	hp or HP			h.p.		P
Hydraulic radius	R_h			R_h														r	r			R_h							
Impulse				Q				Q										I	I	I	Q			K			Q		
Inertia, rectangular moment	I	I	I	I	I		I	I	I	I	I	I	I					J	I		I	I	I	I	I	I	I		
Inertia, polar moment of	J	l	l	I_p		l	l	l	L, l		L	l	l	l				J_p	I_p	l	I_p	L	l	l or L	L	l	J		
Length	L			l	l		l	l			L							l	l	l	l	L	l				l		
Linear acceleration	a			a	a		a	a	a	a	j			a				a	a	a	a_e	a		a			a		
Linear distance	s			l	s		s	s			s			s				s	s	s	l	s			s		s		
Linear velocity	v			V	v		v	v	v		v, V			v				v	v	v	V	v	b	b	b		b		
Load, unit		w	w	w	w		w	w				w	w	w						w	w	b	w	w		W	W		
Load, concentrated		P		P				P				P	P	P				P	P	P	W			P	P		P, W		
Load, total	W	W	W	W	W		W	W	W		W	W	W	W				W	W	W	W	W	W		W	W	W		
Load, eccentricity of	e			e				e				e	e	e				e	e	e		e		e			e		
Mass	m			m	m	m	m	m, M	m, M		m		m	m				m	m	m	m	m	m	m	$\frac{W}{g}$		m, M		
Modulus of elasticity	E	E	E	E			E	E	E	E	E	E	E	E				E	E	E	E	E			E	E	E		E	
Modulus of rupture																													
Modulus of section	Z	S	S	Z								Z		Z				S	S	$\frac{I}{c}$	Z	S	Z	S	Z	S	Z		Z	
Moment, bending	M	M	M	M or M_b	M		M	M			M	M	M	M				M	M	M	M or M_y	M		M	M_b	M	M			
Moment, torsion				M_t																	M_{tr}								
Moment of inertia, rect.	I	I	I	I	I		I	I	I	I	I	I	I	I				J	I	I	I	I		I	I	I	I		I	J
Moment of inertia, polar	J			I_p				J			J	J	J	J				J_p	I_p		I_p	J		J	I_p		J			
Neutral axes thru c. of g.		X-X		X-X			X-X	X-X			X-X	X-X	X-X	X-X							X-X	X-X		X-X		X-X	X-X			
		Y-Y		Y-Y			Y-Y	Y-Y			Y-Y	Y-Y	Y-Y	Y-Y							Y-Y	Y-Y		Y-Y		Y-Y	Y-Y			
Neutral axis not thru c. of g.		N-N		N-N			N-N	N-N			N-N	N-N	N-N	N-N							N-N	N-N		N-N			N-N		
Number of revolutions per unit of time	N			N	n	n					n	N	N	N	n	N	n		N	n	N	n	N	n	N		N		
Period (Harmonic motion)				T			T	P			T											P	T	T			P		
Pitch				p	P						p	p	p	p					p	p		p		p		P	p		
Polar, moment of inertia	J			I_p or J				J			J	J	J	J					I_p		I_p	J		J	I_p		J		
Power, horse	hp			N			$H-P$	h.p.	H.P.				hp						hp	hp	HP	HP		hp	hp or HP		hp		
Pressure		p		P								P	P	P					P, p		p	P	P	p	p		p		
Quantity of liquid flowing	Q			Q																									
Radius	r			r	r		r	r	r		r	r	r	r	r	r			r	r		r	r	r	r		r		R	
Radius of gyration	k	r	r	i	k		k	k			r_0	k	k	k				k	ρ	K		ρ		R	k	r	k			
Radius of curvature				ρ	ρ		ρ	ρ			ρ			ρ					ρ	ρ	ρ	r		ρ			ρ			
Reactions	R	R	R	R				R			R	R	R	R					R	R	R		R_1, R_2, etc.	R	R	R	R			
Rectangular moment of inertia	I	I	I	I	I		I	I	I	I	I	I	I	I					I	I	I	I		I	I	I	R			
Resultant, system of forces							R	R			R	R	R	R				R	R	R	R	R	R	R			N			
Revolutions per unit of time	N			n	n	n					n	N	N	N				n	n	n	N	n		n	N		N		n	
Rotation, center of	O			O			O, C	O			O	O	O	O						O	O	O	O	O			O		
Rupture, modulus of														R										K					
Specific gravity				r																			s.g.	s	s		D_s		s	
Stress, unit	S	f		S			S	S			S	S	S	S				f	f	s	S	s		s			t			
Temperature												T	t	T					T	t	T	t		θ						
Thickness		t	t	T, t														t	t	t	t	t	h	t	t	t	t		t	
Time	t			t	t	t	t	t	t, T	t	t	t	t	t				t	t	t	t	t	t	t	t		t		t	
Torque	T			M_t				T				T	T	T				T	T	T	T	T	T	T	T		T			T
Total load	W	W	W	W	W		W	W	W		W	W	W	W					W	W	W	W	W	W	P	W	W			
Unit load		w	w	w	w		w	w				w	w	w					w	w	w	W	w	w	g	w	w			
Unit stress	S	f		S			S	S			S	S	S	S					f	s	s	s	S	S	S	f	f			
Velocity, angular	ω			ω	ω		ω	ω			ω			ω				ω	ω	ω	ω	ω		ω	ω		ω		ω	
Velocity, linear	v			v	v			v	v		v			v				v	v	v	V	v	v	v	v		v		v	v
Volume	V			V				V					V	V																
Weight (see load)																				W									
Width			b	b	b							b	b	b					b	b	b	b	b	b	b	b	U			
Work				U			U					U	U					W	W		U	W		W or W						
Young's modulus of elasticity	E	E	E	E			E	E	E	E	E	E	E	E					E	E	E	E	E	E	E	E	E			

ODE OF REFERENCES.

Column
29 S. A. Moss, Gen. Elec. Co.
30 D. C. Jackson, Mass. Inst. of Tech.
31 DIN 1350.
32 Amer. Eng. Std's Committee, Aero. Section.
33 Gordon Thompson, Elec. Testing Lab.
34 W. E. Brooke, Univ. of Minnesota.
35 E. F. Church, Jr., Brooklyn Poly. Inst.
36 R. L. Daugherty, Cal. Inst. of Tech.
37 H. B. Langille, Univ. of Cal.

Column
38 L. J. Johnson, Harvard Univ.
39 R. H. Fernald, Univ. of Pennsylvania.
40 W. H. Kenerson, Brown University.
41 W. R. Bryans, New York University.
42 A. H. Beyer, Columbia University.
43 C. L. Eckel, Univ. of Colorado.
44 R. G. Dukes, Purdue University.
45 R. J. Fogg, Lehigh University.
46 R. A. Dodge-Franklin, Univ. of Mich.

Column
47 R. S. Swinton, Univ. of Mich.
48 Stevens, Univ. of Mich.
49 R. T. Liddicoat, Univ. of Mich.
50 Vanden Brock, Univ. of Mich.
51 King, Univ. of Mich.
52 Menefee, Univ. of Mich.
53 C. E. Magnusson, Univ. of Wash. (Seattle).
54 M. L. Enger, Univ. of Illinois.
55 R. L. Sackett, Penn. State College.

29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	Consensus of opinion	
				α	α		α	α	α	α	α	α	α	α	α	α	α	α	α	α	α	α	α	α	α	α	α	alpha
ϑ		ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	ϑ	
	a			a	a		a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a		a	a	a	a	
				β	θ		θ	θ	θ	θ	θ	θ	θ	θ	θ	θ	θ	θ	θ	θ	θ	θ		θ	θ	θ	θ	theta
	ω		ω	ω	ω		ω	ω	ω	ω	ω	ω	ω	ω	ω	ω	ω	ω	ω	ω	ω	ω		ω	ω	ω	ω	omega
A	A		S	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	a	A	A	A	
				X–X	X–X		X–X	X–X	X–X	X–X	X–X	X–X	Z–Z	X–X	X–X	X–X	X–X	X–X	X–X	X–X	X–X	X–X	X–X	X–X		H–H	X–X	
				Y–Y	Y–Y		Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y		V–V	Y–Y	
				N–N	N–N		N–N	N–N	N–N	N–N	N–N	N–N	N–N	N–N	N–N	N–N	N–N	N–N	N–N	N–N	N–N	N–N	N–N	N–N		N–N	N–N	
					M		M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	b	M	M	M	M	
				b	b		b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b		b	b	b	b	
μ		μ		O	O	μ	O	O	O		O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	
				σ	μ		μ	μ	μ		f	μ	μ	μ	f	μ	f	μ	μ	f		f	μ	μ	μ	f	μ	mu
				ϕ	a		a, b or c							δ	a													
				F	P		P	P	P		P	P	P	P	P	P or W	P	P	P		P	Cck	P	P	P	P	P	
				c	c_1, c_2, etc.		c, k	C	C, K		K	K	C	C	C	C	C	ck	C	C	C, K		C	K	C		C	
					R		ρ	ρ	ρ		ρ	ρ	ρ	ρ	ρ	ρ	ρ	r	ρ	ρ	R		ρ	ρ	ρ	ρ	ρ	rho
					e		e	e				e	e	e	e	n	e	μ			μ		e	e	e	h	e	epsilon
				y	y		y	y	y or D		y	y	Δ	y	y		y	$\Delta\delta$	y or Δ	Δ	Δ		Δ_y, Δ_z	Δ, δ	y	y	y	
		γ		δ	σ		γ or δ							δ		δ	r			r		r				δ		
				d	d		d	d	d		d	d	d	d	d	d	d	h-d	d	d		D	d	d	d	d	d	
D		d, ϕ		D	D	D	d or D	D	D or d		D	D	D	D	D	d or D	D	D	D	D	D	d	D	D	d	D	D	
				β	θ		θ	θ	θ		θ	θ	θ	θ	θ	θ	θ	θ	θ	θ	θ		θ	θ	θ	θ	θ	theta
				l	S		s	s or l	s		s	s	s	s	s	θ	s	s	s	s	s		θ	s	θ	s	s	
				f	c		c	c	y_1 or y_2		c	c	c	c	c	c	c	c	c	c	c		s	n	c	c	c	
				e	e		e	e	q or e		e	e	e	e	e	e	e	$e(x$ or $y)$	e	e	e	E	c	e	e	e	e	
$\eta_h\eta_m\eta_p$	ne			$c_h c_m c_p$	$\eta_h\eta_m\eta_p$	e	$c_h c_m c_p$	$\eta_h\eta_m\eta_p$			Eff			c_h etc.		$c_h c_m c_p$	$E_{h,m,p}$	E	$E_{h,m,p}$						$c_h c_m c_p$	e		$c_h c_m c_p$	
				E	E		E		E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	
				λ	δ		ϵ		λ	λ	λ	δ	a	e	e	e, ϵ	δ	δ	δ	δ	Δ		δ	λ	e	Δ	δ	delta
							δ					ϵ			δ													
F	F			P	F or P	F	F or P	F	P or F	P	F	P	F	F	F, P		F	F	F	F	F		F	F	F	P	F	
				f	M		M	M	M	M	M	M	M	M	M	M	M	M	M	M	M		M	M	M	M	M	
					n		n		n	n		n	n	n		$1/T$	n	n	n	n							n	
μ				σ	μ	μ	μ	μ	μ	μ	f	μ	μ	μ	f	μ	f	μ	μ	f	f		μ	μ	μ	f	μ	mu
				ϕ	a		a, b or c			c				δ	a													
					g		g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	
				H	k		k	k	k, r		r	k	k	k	k	k, K	k	k	k	k	k	k	k	H	k	k	k	
				h	H		H	H, h			H	H	H	H	H	H	H	H	H	H	H	H	H		H	H	H	
					h		h		h		h	h	h	h	h	h	h	h	h	h	h	h	h		h	h	h	
P					hp	P	hp	HP or HP	P	H.P.	H.P.	H.P.	hp	hp	hp	hp or HP	HP	HP	H.P.	H.P.	H.P.	H.P.	hp	H.P.	H.P.	hp	H.P.	H.P.	
					R		m (or R)	r		R_h		R_h		m		r	r	r	r				r	r	R	r		r	
				I	I		Q		I (I_x or I_y)	Q	Q		I	Q	I	Q	Q	I	Q			$I_x I_y$	Q		Q		Q	
				J	J		J	J	I_r	J	J	J	J	J	J	$II_x I_y$	J	J	J	J	J	I_x	I	J	I	J	I	
				l	l		L or l	l	l	L	L	l	L or l	L	l	J or I_p	L	L. l.	L. l.	L	L	I_y	L	L	l	l	l	
				a	a		a	a	a	a	a	a	a	a	a	L	a	a	a	a	a		a	a	a	a	a	
				l	s		s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	v, V	s	s	s	s	s	
				v	v		V or v	v	v	v	v	v	v	v	v	$v_1 v_2 v_3 v_4$	V	V	V	v	V		v	V	v	V	v	
				w	w		w	w	w	w	w	w	w	w	w	w	w	w	w	w	w		w	w	w	w	w	
				F	P		P	P	P	P	P	P	P	P	P	P or w	P	P	P	P	P		P	P	P	P	P	
				W	W		W	W	W	W	W	W	W	W	W	W	W	W	W	W	W		W	W	W	W	W	
					e		e	e	e or g	e	e	e	e	e	e	e	e	e	e	e	e		e	e	e	e	e	
		$m=\frac{G}{g}$		m	m		m or M	m	$\frac{W}{g}$ or m	e	M	m	m	M	M	m, $\frac{W}{g}$	m	m	m	m	M	M	m		m, M	M	m	
E		E		E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	
					$\frac{I}{c}$									s_v															
Z						Z	Z	Z	S	Z		Z	Z	f	$\frac{I}{c}$	$\frac{I}{c}$	S	S	Z				Z	s			Z	
		M		M_b	M		M	M	M	M	M	M	M	M	M	M	M	M	M	M	M		M	M	M	M	M	
				M_t	$T.M$		T	T	T	M	M	M	T	T	T	T	T	T	T	T	T		T	M_t	T		T	
	I	J, J_n			I		I	I	I (I_x, I_y)	I	I	I	I	I	I	$II_x I_y I_z$	I	I	I	I	$I_z I_y$	I	I	I	I	I	
		J_p			J		J	J	I_z	J	J	J	J	J	J	J or I_y	J	J	J	J	I_x		J	J	I_p	J	J	
				X–X	X–X		X–X	X–X	X–X	X–X	X–X	X–X	X–X	X–X	X–X	X–X	X–X	X–X	X–X	X–X	X–X		X–X		X–X	H–H	X–X	
				Y–Y	Y–Y		Y–Y	Y–Y	Y–Y		X–X	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y	Y–Y		Y–Y		Y–Y	V–V	Y–Y	
				N–N	N–N		n or N	N (rpm)	n	N	N	N or R.P.M.	N	N	N	N–N or N–A	N–N	R.P.M.	N–N	N–N	N–N	N–N	N	N–N	N	n	X–X	N–N	
																		R.P.S.								R.P.M.		
				T	T		P	T			T			T	T	T	T	N	T	T	T		T		P		T	
				J	J		J	J	I_z	J	J	J	J	J	J	J or I_p	J	J	J	J	I_0		J	J	J	I_p	J	
					hp		hp	HP or HP	P	H.P.	H.P.	H.P.	hp	hp	hp	hp	HP	HP	H.P.	H.P.	H.P.	hp	H.P.	H.P.	hp	H.P.	H.P.	
					p		p or P	p	P, p	P	P	H.P.	P	P, p	P	hp	P	P	P	P	P		P	P	P		P	
R		r			Q	R	q	Q		Q	Q	Q	Q	Q		Q	Q	Q	Q			Q	Q	Q	Q		Q	
				r	r		r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	R	r	r	r	r	r	
				k	k		k	k (l.c.)	k or r	r	k	k	k	k	k	h	k	k	k	k	k	k	k	k	k	k	k	
				ρ	R		ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	r	ρ	ρ	R		ρ	ρ	ρ	ρ	ρ	rho
		A		R	$R_1 R_2$		R	R	R	R	R	$R_1 R_2 R_3$	R	R	R	I, $I_x I_y I_z$	R	R	R	R	R_1 etc.		R	$R_1 R_2$	R	R	R	
		R		I	I		I	I	I (I_y)	I	I	I	I	I	I		I	I	I	I	$I_z I_y$	I	I	I	I	I	I	
				R	R		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	I	R	R	R	R	R	
n				N	N	n	n or N	N (rpm)	n	N	N	R.P.M. or N	N	N	N	n, N	N	N	N	N	N	N	N	N	n	R.P.M.	N	
				O	O		O	O	O	O	O	O	O	O	O	O	O	O	O	O			O	O	O	O	O	
							s_r							s_v														
s							S									sp gr												
				Θ, θ	t		S	s	f	s	s	S	S	s	s	S	s	s	s	s	f		s	f	s	s	s	
							T, t, τ	T, t	T	s	T	t	T	t	t	T or t	t	t			t		t	T	T	t	t	
				t	t		t	t	t	t	t	t	t	t	t	t	t	t			t	t	t	t	t	t	t	
t				T	t	t	T or t	t	t	t	t	t	t	t	t	t	T, t	T, t			t	T, t		t	t	t	t	
	T			M_t	T		T	T	T	T	T	T	T	T	T	T	T	T			T	T		T		T	$T(M)$	T	
			Q		W		W	W	W	W	W	W	W	W	W	W	W	W			W	W		W	W	W	W	W	
				w	w		w	w	w	w	w	w	w	w	w	w	w	w			w	w		w	w	w	w	w	
ω				s	S		S	S	f	s	s	s	S	S	S	s; f_c or f_s	s	s			s	f		s	f	S or s	s	s	
				ω	ω	ω	ω	ω	ω	ω	ω	ω	ω	ω	ω	ω	ω	ω			ω	ω		ω	ω	ω	ω	ω	omega
v		v		v	v	v	V or v	v	v	v	v	v	V	V	V	$v_1, v_2 v_3 v_4$	V	V			v	v		v	V	v	V	v	
V	V	V		V	V	V	V	V	V	v	Vel.	V	V	V	V	V	V	V			V	V		V	V	V	V	V	
			W	W	W											W or P		mg			W			W	W			W	
				b	b		b	b	b	b	b	b	b	b	b	b	b	b			b	b		b	b	b	b	b	
				U	U	E	u			U	Wk	U	U	U	U	U	W	W				W		W	U	w	W	U	
				E	E		E	E	E	E	E	E	E	E	E	E	E	E			E	E		E	E	E	E	E	

compiled just as received, there being 55 sources of information charted on this table. The extreme right-hand column shows the symbols upon which there appears to be reasonable agreement. Where no symbol is shown, no general agreement exists.

The table is interesting as indicating a practical agreement upon many of the commoner symbols in mechanics, structural engineering, and testing of materials. The column at the right, marked *Consensus of Opinion*, which indicates the extent to which agreement occurs among these 55 sources, is merely a step in the process, and is not a recommended list of symbols. Before a recommended list can be obtained by the subcommittee of the American Engineering Standards Committee, these symbols will have to be compared with the symbols which have been selected tentatively or finally by the other subcommittees. For instance, some of the committee members have insisted that no symbol for *load* or *weight* is required, since a symbol for *force* is available, and that it will be necessary for engineers who have become accustomed to believing that the letter P is the proper symbol for *load* to give way and adopt F, the symbol for *force*, in order that P may be available for another concept. There seems also to be a fundamental objection to the use of the symbol suggested for *horsepower*, it being maintained by some that the use of a combination of two letters for a symbol leads to confusion and is liable to lead to serious error.

The information in the table is submitted for the benefit of those who are interested in symbols for mechanics, structural engineering, and testing of materials. It is hoped that those who feel inspired to offer any criticism or suggestions now, while the report of this subcommittee remains still to be made, will send these criticisms and suggestions promptly to the Secretary of the Society for the Promotion of Engineering Education, who will forward them to the subcommittee having this matter in charge.

So far as the writer knows, the various reports being prepared under the auspices of the American Engineering Stand-

ards Committee upon engineering symbols and abbreviations represent the most comprehensive and best coordinated effort made in this country up to this time.

JOHN T. FAIG, *Chairman,*
Committee No. 20.

June, 1928.

JOINT SESSION OF S. P. E. E. AND A. S. M. E.

DEAN D. S. KIMBALL, *President,*
Society for the Promotion of Engineering Education,
Cornell University, Ithaca, New York.

My dear Dean Kimball:

On behalf of our Council, it gives me special pleasure to invite the Society for the Promotion of Engineering Education to sponsor jointly with our Committee on Education and Training for the Industries, the session on Education and Training to be held Tuesday afternoon, December 4, during our Annual Meeting that week.

There will be many social events during the meeting, in all of which your officers and members are most cordially asked to participate.

Sincerely yours,
(Signed) CALVIN W. RICE, *Secretary,*
American Society of Mechanical Engineers.

October 18, 1928.

The entire session on Education and Training scheduled for Tuesday afternoon, December 4, at 2:00 p.m., in the Engineering Societies' Building, 33 West 39th Street, New York, will be devoted to the S. P. E. E. study of non-college technical education.

Robert H. Spahr of the S. P. E. E. staff will present a paper entitled, "Preliminary Findings of a Study of Intensive Types of Technical Education." This paper will be discussed by members of the cooperating societies and invited guests. It is hoped that many members of the S. P. E. E. will attend.

PHYSICS DIVISION.*

1. The undersigned members of the Society for the Promotion of Engineering Education request the Council to authorize the formation of a Physics Division of the Society in accordance with the provisions of Article VII of the Constitution.

2. It is suggested that the following individuals (with the addition of two others as stated in paragraph 3 below) be appointed to serve as an executive committee of the Division until the annual meeting of 1929:

W. N. St. Peter (*Chairman*), A. W. Duff,
W. R. Wright, W. S. Franklin,
O. M. Stewart.

3. It is further suggested that the above named committee recommend the appointment of two additional members to serve until the annual meeting of 1929.

4. The activities of the Division proposed for the ensuing year are as follows:

(*a*) The enlisting of the interest of as many teachers of Physics as possible in the work of the Society and in the activities of the Physics Division.

(*b*) The arranging of a session on Physics in connection with the annual meeting of the Society in 1929.

(*c*) The arranging of other activities in connection with the teaching of Physics as may be deemed desirable by the proposed executive committee of the Division.

(signed) A. W. Duff, A. W. Doll,
W. N. St. Peter, T. F. Garner,
W. L. Severinghaus, W. F. Brown, Jr.,
W. R. Wright, L. A. Doggett,
Wm. S. Franklin, H. P. Hammond,
C. L. Brightman, W. E. Wickenden,
B. M. Stewart, N. E. Wheeler,
W. O. Hall, J. O. Hamilton,
J. C. Gray, F. F. Piper,
Parke B. Fraim, Percy Hodge.

* The Council, by letter ballot, has approved the formation of a Physics Division.

COLLEGE NOTES.

University of Kansas.—*New Appointments:* Ralph D. Baker, Instructor in Mechanical Engineering; Millard F. Dowell, Assistant Instructor Electrical Engineering; E. D. Hay, Professor of Mechanical and Industrial Engineering; Jacob O. Jones, Professor of Hydraulics; R. W. Kehr, Instructor Civil Engineering and Assistant Engr. State Bd. of Health; John A. King, Associate Professor of Mechanical Engineering; Walter McElfresh, Instructor in Applied Mechanics; Verner F. Smith, Instructor in Architecture; Robert W. Warner, Assistant Professor of Electrical Engineering.

Promotions to Heads of Departments: J. M. Kellog, Acting Head of Dept. of Architecture; F. Ellis Johnson, Head of Dept. of Electrical Engineering.

As a beginning of work in aeronautics, the department of Mechanical Engineering is offering two new courses to be known as *Aeroneutical Engineering I* and *Aeronautical Engineering II* each carrying three hours credit.

Pratt Institute.—School of Science and Technology: Two new members were added to the faculty of the school of Science and Technology for the present school year and took up their duties at the beginning of the fall term in September.

Dr. Andrew C. Rice, a graduate of the University of New Hampshire, class 1923, has been added to the department of Chemical Engineering. Dr. Rice held a graduate assistantship at the University from 1923–1925, during which time he worked for his M.S. degree. Following this he entered Columbia University and secured his Doctor's degree in 1928.

Mr. Hugh S. Cameron, a graduate of Stevens Institute of Technology, assumes his duties in the department of Mechanical Engineering. After graduation in 1925 Mr. Cameron was made assistant test engineer with the Brooklyn Union Gas Company. During this time he held an instructorship of Mathematics in the evening school of the Brooklyn Polytechnic Institute.

As the present school term opens work is well under way on the new Engineering Building which is to be devoted to the departments of Mechanical and Electrical Engineering. This will bring the School of Science and Technology important betterment of its facilities for its particular type of engineering education.

REQUEST FOR INVENTIONS OF OCTAVE CHANUTE.

Your name has been suggested to us as a possible aid in establishing the division of transportation and communication in the Rosenwald Industrial Museum. We have been trying for some time to locate some of the original models of the gliders made by Octave Chanute.

It is just possible that you might have some information about Chanute and his work or about any relics of his inventions that would be invaluable to us. May, we, therefore ask the aid of your good offices in this matter?

WALDEMAR KAEMPFFERT, *Director,*
Rosenwald Industrial Museum,
300 West Adams Street, Chicago.

BOOK REVIEWS.

Industrial Engineering and Factory Management. ARTHUR G. ANDERSON, Associate Professor of Business Organization and Operation, College of Commerce, University of Illinois. 1928. xiv + 623 pages. The Ronald Press Company, New York. $5.00.

As stated in the preface, this text is primarily "for students of management and industrial engineering, designed to precede specialized training in any particular management field." The author is an engineer and has drawn much of his material from the engineering viewpoint.

The approach to the subject is first through a review of American industry and its problems. This is very logically followed by a study of the manufacturing plant itself. Many factors ordinarily overlooked or treated in a fashion far removed from engineering procedure are here very adequately covered. Such factors include factory lighting, heating and ventilation, shop transportation and power. Such topics as budgeting, purchasing, tool and stores control, production control are discussed and related to the whole subject of factory management.

The newly graduated industrial engineer frequently enters industry through the shop. To understand properly most shop processes requires a knowledge of certain fundamentals of mathematics, science and engineering application. It would seem, therefore, that the section on operation studies, viewed as it must be against an engineering background, could be enlarged and amplified. This would, of course, detract somewhat from the usefulness of the text for students other than those with the engineering training. On the other hand it would render the text far more useful to industrial executives, as well as to those engaged in industrial engineering education.

The text is well illustrated. Charts and graphs help to clarify the subject matter. Excellent review questions and some case material follow each chapter.

J. W. H.

The Elements of Industrial Engineering. GEORGE HUGH SHEPARD, Professor of Industrial Engineering and Management, Purdue University. 1928. xii + 541 pages. Ginn and Company, Boston, Mass. $4.80.

Professor Shepard has built his text around thirteen so-called "Principles of Management." Three of these are classed as primary and nine as secondary, while one, called "all inclusive" is termed "Higher Common Sense." This is a radical departure from ordinary methods of attack in such a subject, but the author's statements are backed with sufficient quotations and illustrations to support each of the so-called "principles." Their acceptance as all-inclusive "principles of management" is doubtful, but they serve as an excellent approach to the subject.

One very noticeable value of this book lies in the fact that the approach to each topic is through the eyes of the undergraduate student. The explanation of certain points ordinarily passed over by an author with a brief statement is here set forth in clear, logical A-B-C language that cannot fail to impress and instruct the reader.

As indicated by its title, the text serves as an excellent introduction to a study of the functions ordinarily held to be the province of the Industrial Engineer. To educate properly the undergraduate student, many of the topics covered will have to be pursued more intensively but the text points out the inter-relation of the topics covered. In short the book is *the kind* of text for which those interested in the education of undergraduates in industrial engineering have long felt a need.

Excellent case material is contained in problems and exercises at the close of most of the chapters.

J. W. H.